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From: (b)(6)
Sent: Monday, March 04, 2002 3:56 PM
To: (b)(6)
Cc:
Subject: Important - now on the House's web page - G&O is mentioned (I highlighted key parts)

Importance: High

COMMITTEE ON SCIENCE

U.S. HOUSE OF REPRESENTATIVES

HEARING CHARTER

Learning from 9/11: Understanding the Collapse of the World Trade Center

Wednesday, March 6, 2002

Noon to 2:00 p.m.

2318 Rayburn House Office Building

1. Purpose

On Wednesday, March 6, at noon the House Committee on Science will hold a hearing on the investigation into the collapse of the World Trade Center (WTC). Witnesses from industry, academia, and government will testify on the catastrophic collapse of the WTC complex and subsequent efforts by federal agencies and independent researchers to understand how the building structures failed and why. By scrutinizing the steel and other debris, blueprints and other documents, and recorded images of the disaster, engineers, designers, and construction professionals may learn valuable lessons that could save thousands of lives in the event of future catastrophes, natural or otherwise.

The Committee plans to explore several overarching questions raised by the collapse and the ensuing investigation:

1. What have we learned about how the federal government investigates catastrophic building collapses, and are any changes warranted?

2. What have we learned about the collapse of the World Trade Center, including which structural elements failed first, and why?

3. How will we know what changes, if any, are warranted in building and fire codes as a result of lessons learned from the World Trade Center's collapse?

4. Has the World Trade Center disaster exposed any gaps in our understanding of buildings and fire, and are changes needed in the federal government's research agenda?

2. Background

At 8:47 a.m. on the morning of September 11, 2001, terrorists crashed a fuel-laden Boeing 767 into the north tower (Tower 1) of the World Trade Center (WTC) complex. Approximately 16 minutes later, a second Boeing 767 slammed into the south tower (Tower 2), exploding upon impact and engulfing several of the building's upper floors in flames. While the performance of both towers exceeded their design specifications - the buildings were designed to withstand the force from the initial impact of a 707 jet - the subsequent structural and fire damage still caused the buildings to fall. Tower 2 collapsed in less than an hour, killing victims trapped above the flames and rescue workers in and around the building. Thirty minutes later, Tower 1 met the same fate. While more than 25,000 people were successfully evacuated from the towers, nearly 3,000 people and emergency responders were killed in the collapses. As the day progressed, the remaining WTC buildings collapsed as well, including Building 7, which burned for 8 hours before crumbling to the ground. Fortunately, the later building collapses produced no casualties.

In the wake of the collapses, search and rescue workers launched an around-the-clock recovery effort to find and recover survivors and victims who perished. To make way, literally tons of twisted steel and fractured concrete were removed from the rubble pile and loaded onto convoys of bulldozers and flatbed trucks to be carried away to recycling plants and landfills.

Researchers also began to respond immediately. Among the first were National Science Foundation (NSF)-funded social scientists and engineers who arrived at the WTC site within 48 to 72 hours after the tragedy to begin collecting data. Similarly, the American Society of Civil Engineers (ASCE) formed a Disaster Response Team within hours of the first plane strike. On September 12th, **the Federal Emergency Management Agency (FEMA) and its contractor, Greenhorne and O'Mara, Inc., located in Greenbelt, Maryland,** commenced the development of a Building Performance Assessment Team (BPAT; explained more fully on the next page) to conduct a formal analysis of the progressive collapses and produce a report of its findings. A variety of other engineering researchers and professionals, including members of the Structural Engineering Association of New York, also engaged in the monumental task of collecting data that could lead to a better understanding of the collapse of the buildings themselves and to the development of mitigation strategies to prevent a similar tragedy in the future.

Concerns Related to the Engineering Investigation

Though many of the individuals who have participated in the WTC building performance investigation are architects and engineers with experience investigating other structural collapses - including those resulting from natural causes as well as terrorist attacks - nothing had prepared these investigators for a disaster of this magnitude and complexity. Unlike the destruction caused by an earthquake, which may affect several buildings across an expansive area, this disaster involved many buildings and a massive debris pile in a small, confined area. Also unlike most earthquakes, the WTC disaster caused significant casualties and prompted a prolonged search and rescue effort. In addition, the concurrent criminal investigation by the Federal Bureau of Investigation and a separate investigation by the National Transportation Safety Board further frustrated the building performance investigators.

The investigation has been hampered by a number of issues, including:

· No clear authority and the absence of an effective protocol for how the building performance investigators should conduct and coordinate their investigation with the concurrent search and rescue efforts, as well as any criminal investigation: Early confusion over who was in charge of the site and the lack of authority of investigators to impound pieces of steel for examination before they were recycled led to the loss of important pieces of evidence that were destroyed early during the search and rescue effort. In addition, a delay in the deployment of FEMA's BPAT team may have compounded the lack of access to valuable data and artifacts.

· Difficulty obtaining documents essential to the investigation, including blueprints, design drawings, and maintenance records: The building owners, designers and insurers, prevented independent researchers from gaining access - and delayed the BPAT team in gaining access - to pertinent building documents largely because of liability concerns. The documents are necessary to validate physical and photographic evidence and to develop computer models that can explain why the buildings failed and how similar failures might be avoided in the future.

· Uncertainty as a result of the confidential nature of the BPAT study: The confidential nature of the BPAT study may prevent the timely discovery of potential gaps in the investigation, which may never be filled if important, but ephemeral evidence, such as memories or home videotapes, are lost. **The confidentiality agreement that FEMA requires its BPAT members to sign has frustrated the efforts of independent researchers to understand the collapse, who are unsure if their work is complementary to, or duplicative of, that of the BPAT team.** In addition, the agreement has prevented the sharing of research results and the ordinary scientific give-and-take that otherwise allows scientists and engineers to winnow ideas and strengthen results.

· Uncertainty as to the strategy for completing the investigation and applying the lessons learned: **The BPAT team does not plan, nor does it have sufficient funding, to fully analyze the structural data it collected to determine the reasons for the collapse of the WTC buildings.** (Its report is expected to rely largely on audio and video tapes of the event.) Nor does it plan to examine other important issues, such as building evacuation mechanisms. Instead, FEMA has asked the National Institute of Standards and Technology (NIST) to take over the investigation. Yet so far, NIST has not released a detailed plan describing how it will take over the investigation, what types of analyses it will conduct, how it will attempt to apply the lessons it learns to try to improve building and fire codes, and how much funding it will require.

Role of the Federal Emergency Management Agency

The Federal Emergency Management Agency is charged with supporting the nation's emergency management system. FEMA intervenes at all stages of disaster management including preparation, response, recovery, mitigation, risk reduction, and prevention. In the case of the World Trade Center attack, FEMA dispatched Urban Search and Rescue Teams and established a disaster field office at the site within hours of the first strike to assist in New York City's rescue effort. At the same time, the FEMA Building Performance Assessment Team (BPAT) began their important work of initiating an analysis that could ultimately yield valuable information about the sequence of events and failures that resulted in progressive building collapse.

BPATs are routinely deployed by FEMA following disasters caused by events such as floods and hurricanes. The teams are formed by, and operate under the direction of the Mitigation Directorate's Program Assessment and Outreach Division and comprise such individuals as regional FEMA staff, representatives from state and local governments, consultants who are experts in engineering, design, construction, and building codes, and other technical and support personnel. **A contractor for FEMA, Greenhorne & O'Mara, Inc., maintains a roster of hundreds of mitigation specialists from across the United States. BPAT teams are typically deployed within seven days of any disaster event.**

Generally, a BPAT conducts field inspections and technical evaluations of buildings to identify design practices, construction methods, and building materials that either failed or were successful in resisting the forces imposed by the event. A major objective of the BPAT's findings and recommendations are aimed at improving design, construction and enforcement of building codes to enhance performance in future disasters. The culmination of the BPAT's efforts is a report that presents the team's observations, conclusions, and recommendations for improving building performance in future natural disasters.

The BPAT team deployed to the WTC site was assembled by the American Society of Civil Engineers and is headed by W. Gene Corley, Ph.D., P.E, Senior Vice President of Construction Technologies Laboratory in Skokie, Illinois. He was also the principal investigator in the FEMA study of Oklahoma City's Murrah Federal Office Building. On September 11th, ASCE, in partnership with a number of other professional organizations, commenced the formation of an independent team of experts to conduct a building performance assessment study at the WTC site as part of ASCE's Disaster Response Procedure. In late September, this team, the ASCE Disaster Response team, was officially appointed as the BPAT team and was funded by FEMA to assess the performance of the buildings and report its findings. The BPAT team received $600,000 in FEMA funding in addition to approximately $500,000 in ASCE in-kind contributions.

The 23-member BPAT team conducted an analysis of the wreckage on-site, at Fresh Kills Landfill and at the recycling yard from October 7-12, 2001, during which the team extracted samples from the scrap materials and subjected them to laboratory analysis. Why the analysis was conducted only after a delay of three weeks after the attacks remains unclear. Since November, members of the Structural Engineers Association of New York (SEAoNY) have volunteered to work on the BPAT team's behalf and are visiting recycling yards and landfills two to three times a week to watch for pieces of scrap that may provide important clues with regard to the behavior of the buildings.

In the month that lapsed between the terrorist attacks and the deployment of the BPAT team, a significant amount of steel debris - including most of the steel from the upper floors - was removed from the rubble pile, cut into smaller sections, and either melted at the recycling plant or shipped out of the U.S. Some of the critical pieces of steel - including the suspension trusses from the top of the towers and the internal support columns - were gone before the first BPAT team member ever reached the site. Fortunately, an NSF-funded independent researcher, recognizing that valuable evidence was being destroyed, attempted to intervene with the City of New York to save the valuable artifacts, but the city was unwilling to suspend the recycling contract. Ultimately, the researcher appealed directly to the recycling plant, which agreed to provide the researcher, and ultimately the ASCE team and the SEAoNY volunteers, access to the remaining steel and a storage area where they could temporarily store important artifacts for additional analysis. Despite this agreement, however, many pieces of steel still managed to escape inspection.

The BPAT team is expected to release its report in April. Because FEMA requires the members of its BPAT team to sign a confidentiality agreement until the report is released, the exact scope of the report is unknown. But it appears from the role that BPAT teams normally play and general comments ASCE members of the BPAT team have made that the report is likely to include an examination of how the buildings behaved leading up to the collapse, hypotheses for which structural elements failed and thereby initiated the collapse, and recommendations for additional research and analysis.

For example, ASCE has said that the study will rely primarily on audio and video recordings, interviews with survivors, blueprints and design drawings of the World Trade Center, and evidence they or the SEAoNY volunteers have collected from the rubble. The BPAT team has access to more than 120 hours of high quality film footage and audiotapes of 911 communications with trapped victims. The BPAT team initially had difficulty in obtaining building blueprints and design drawings from either the City of New York, the Port Authority, the building owners, or the building designers due primarily to liability concerns on the part of the building owners and insurers. Belatedly, however, the team was provided access to these documents in early January.

ASCE has said that the BPAT study will not include an analysis of the evacuation or rescue procedures and may not be able to validate definitively any of a number of hypotheses regarding the collapse. But because of the confidentiality of the report, it is unclear whether the it will provide answers or simply lay out more questions. It is unknown, for example, to what degree the BPAT report will compare video evidence with that collected from the steel beams from the floors that were hit by the planes.

As a result, independent researchers are unsure how they can contribute to the understanding of how the buildings fell without unnecessarily duplicating work. Others fear that the BPAT's silence on the scope of its report may allow critical aspects of the picture to be missed, and that, by the time the report is released and any such gaps are discovered, the trail of evidence that could provide answers may have grown cold.

The National Science Foundation

Researchers supported by the National Science Foundation are used to mobilizing rapidly after an earthquake and arriving on scene soon after the event to begin collecting data. Recognizing the similarities between the WTC disaster and earthquakes, NSF program managers awarded nearly $300,000 to experienced earthquake researchers, including engineers and social scientists, to begin an analysis of the 9/11 terrorist attacks within 72 hours of the events. In an effort to quickly deploy researchers to the site, awards were made through the Small Grants for Exploratory Research Program, a supplemental award program that enables NSF program managers to award additional support to currently-funded investigators through an abbreviated internal review process (see Appendix A for a list of awards).

The efforts of NSF-funded researchers were impeded by the same obstacles the BPAT team encountered: an inability to examine the steel, either removed from the site during the early search and rescue work or shipped to recycling plants, and the denial of access to building design, construction and maintenance documents. Interestingly, it was an NSF-funded researcher who ultimately negotiated the arrangements by which he and others investigating the disaster were provided access to the remaining pieces of steel at the recycling plant.

To date, the NSF-funded researchers continue to face problems. They continue to be denied access to important building diagrams and blueprints, and so are unable to complete their analyses or develop the computer models necessary to better understand the failure of the buildings structural elements. Perhaps more importantly, without these computer models, engineering researchers will be unable to develop effective mitigation strategies.

The National Institute of Standards and Technology

NISTs Building and Fire Research Laboratory carries out research in fire science, fire safety engineering, and structural, mechanical, and environmental engineering. It is the only federal laboratory dedicated to research on building design and fire safety. In the past, the lab has investigated several structural failures using authority Congress made explicit in 1985. (15 U.S.C. 282a). The goals of its previous investigations were to determine the probable technical causes of the failures, examine what lessons could be learned from those determinations, and help develop improved building codes, standards, and practices. The investigations also identified areas of research that needed further study.

Shortly after the attack, NIST appointed an employee of the Building and Fire Research Laboratory to serve on the 23-member BPAT team. While this partnership lent some of NIST's resources and expertise to the BPAT study, NIST did not immediately launch a formal investigation into the technical causes that led to the collapse of the World Trade Center buildings.

NIST believes that the World Trade Center collapse raises difficult and technical questions regarding building codes and standards, justifying the redirection of funds to its building and fire lab. For example, standards for concrete design, building loads, and structural integrity may need revision. In response, NIST has redirected $2 million of its fiscal year

2002 internal discretionary funds to the lab to supplement its current building engineering and standards work. NIST has also requested permission to reprogram from the rest of its laboratories another $2 million in fiscal year 2002 funds for these efforts. The reprogramming request is currently pending before the Office of Management and Budget and will ultimately need approval from Congress. NIST did not need Congressional review to redirect its discretionary funds.

In January, after a delay of three months since the terrorists' attacks, FEMA asked NIST to take over the next phase of the investigation of the collapse. Yet neither NIST nor FEMA has released details as to what that next phase would entail (other than the general outline NIST has provided below). In addition, the Administration has not yet indicated whether FEMA, NIST, or a supplemental funding request to Congress would provide funds for such an investigation, nor has it identified how much it would cost.

Administration officials and outside parties are weighing whether a formal arrangement should be made for NIST to serve as FEMA's research arm in the event of future catastrophic building failures. Currently, there is no formal relationship between the two agencies regarding these matters.

Based on some initial planning, NIST has preliminarily identified the following general areas for investigation:

· Determine technically, why and how the buildings collapsed (WTC 1 and 2, and possibly WTC 7);

· Investigate the technical aspects of fire protection, response, and evacuation, and occupant behavior and response;

· Determine whether state-of-the-art procedures were used in the design, construction, operation, and maintenance of the WTC building;

· Determine whether there are new technologies and procedures emerging that could be employed in the future to reduce the potential risks of collapse; and

· Identify building and fire codes, standards, and practices that warrant revision.

3. Questions

Please see Appendix A for copies of letters to witnesses and the questions each was asked to address in testimony at the hearing.

4. Witnesses

The following witnesses will address the subcommittee:

Mr. Robert Shea, Acting Administrator Federal Insurance and Mitigation Administration, and, Mr. Craig Wingo, Director of Division of Engineering Science and Technology, Federal Emergency Management Administration

Dr. W. Gene Corley, P.E., S.E., American Society of Civil Engineers, Chair of the Building Performance Assessment Team reviewing the WTC disaster

Professor Glenn Corbett, Assistant Professor of Fire Science at John Jay College, New York City

Dr. Abolhassan Astaneh-Asl, Professor, Department of Civil and Environmental Engineering University of California, Berkeley

Dr. Arden Bemet, Director, National Institute of Standards and Technology

5. Additional Reading

Glanz, J. (2001, December 4). Wounded Buildings Offer Survival Lessons. The New York Times, p. F1

Glanz, J., & Lipton, E. (2001, December 25). A National Challenged: The Towers; Experts Urging Broader Inquiry in Towers' Fall. The New York Times, p. A1

Glanz, J., & Lipton, E. (2002, January 17). New Agency to Investigate the Collapse of Towers. The New York Times, p. B3

Glanz, J., & Lipton, E. (2002, February 2). At Scrapyards, as Search for Clues in the Towers' Collapse. The New York Times, p. B1

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Witness List

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Acting Administrator,
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and
Mr. Craig Wingo
Director,
Division of Engineering Science and Technology,
Federal Emergency Management Administration

Dr. W. Gene Corley
American Society of Civil Engineers,
Chair of Building Performance Assessment
Team reviewing the WTC disaster

Professor Glen Corbett
Assistant Professor of Fire Science,
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Dr. Abolhassan Astaneh-Asl
Professor,
Department of Civil and Environmental
Engineering,
University of California, Berkeley

Dr. Arden Bement
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Section 210 of the Congressional Accountability Act of 1995 applies the rights and protections covered under the Americans with Disabilities Act of 1990 to the United States Congress. Accordingly, the Committee on Science strives to accommodate/meet the needs of those requiring special assistance. If you need special accommodation, please contact the Committee on Science in advance of the scheduled event (3 days requested) at (202) 225-6371 or FAX (202) 225-0891.

Should you need Committee materials in alternative formats, please contact the Committee as noted above.

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The investigation has been hampered by a number of issues, including:

- **No clear authority and the absence of an effective protocol for how the building performance investigators should conduct and coordinate their investigation with the concurrent search and rescue efforts, as well as any criminal investigation:** Early confusion over who was in charge of the site and the lack of authority of investigators to impound pieces of steel for examination before they were recycled led to the loss of important pieces of evidence that were destroyed early during the search and rescue effort. In addition, a delay in the deployment of FEMA's BPAT team may have compounded the lack of access to valuable data and artifacts.

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- **Uncertainty as a result of the confidential nature of the BPAT study:** The confidential nature of the BPAT study may prevent the timely discovery of potential gaps in the investigation, which may never be filled if important, but ephemeral evidence, such as memories or home videotapes, are lost. The confidentiality agreement that FEMA requires its BPAT members to sign has frustrated the efforts of independent researchers to understand the collapse, who are unsure if their work is complementary to, or duplicative of, that of the BPAT team. In addition, the agreement has prevented the sharing of research results and the ordinary scientific give-and-take that otherwise allows scientists and engineers to winnow ideas and strengthen results.

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To date, the NSF-funded researchers continue to face problems. They continue to be denied access to important building diagrams and blueprints, and so are unable to complete their analyses or develop the computer models necessary to better understand the failure of the buildings structural elements. Perhaps more importantly, without these computer models, engineering researchers will be unable to develop effective mitigation strategies.

The National Institute of Standards and Technology

NISTs Building and Fire Research Laboratory carries out research in fire science, fire safety engineering, and structural, mechanical, and environmental engineering. It is the only federal laboratory dedicated to research on building design and fire safety. In the past, the lab has investigated several structural failures using authority Congress made explicit in 1985. (15 U.S.C. 282a). The goals of its previous investigations were to determine the probable technical causes of the failures, examine what lessons could be learned from those determinations, and help develop improved building codes, standards, and practices. The investigations also identified areas of research that needed further study.

Shortly after the attack, NIST appointed an employee of the Building and Fire Research Laboratory to serve on the 23-member BPAT team. While this partnership lent some of NIST's resources and expertise to the BPAT study, NIST did not immediately launch a formal investigation into the technical causes that led to the collapse of the World Trade Center buildings.

NIST believes that the World Trade Center collapse raises difficult and technical questions regarding building codes and standards, justifying the redirection of funds to its building and fire lab. For example, standards for concrete design, building loads, and structural integrity may need revision. In response, NIST has redirected $2 million of its fiscal year 2002 internal discretionary funds to the lab to supplement its current building engineering and standards work. NIST has also requested permission to reprogram from the rest of its laboratories another $2 million in fiscal year 2002 funds for these efforts. The reprogramming request is currently pending before the Office of Management and Budget and will ultimately need approval from Congress. NIST did not need Congressional review to redirect its discretionary funds.

In January, after a delay of three months since the terrorists' attacks, FEMA asked NIST to take over the next phase of the investigation of the collapse. Yet neither NIST nor FEMA has released details as to what that next phase would entail (other than the general outline NIST has provided below). In addition, the Administration has not yet indicated whether FEMA, NIST, or a supplemental funding request to Congress would provide funds for such an investigation, nor has it identified how much it would cost.

Administration officials and outside parties are weighing whether a formal arrangement should be made for NIST to serve as FEMA's research arm in the event of future catastrophic building failures. Currently, there is no formal relationship between the two agencies regarding these matters.

Based on some initial planning, NIST has preliminarily identified the following general areas for investigation:

- Determine technically, why and how the buildings collapsed (WTC 1 and 2, and possibly WTC 7);
- Investigate the technical aspects of fire protection, response, and evacuation, and occupant behavior and response;
- Determine whether state-of-the-art procedures were used in the design, construction, operation, and maintenance of the WTC building;
- Determine whether there are new technologies and procedures emerging that could be employed in the future to reduce the potential risks of collapse; and
- Identify building and fire codes, standards, and practices that warrant revision.

3. Questions

Please see Appendix A for copies of letters to witnesses and the questions each was asked to address in testimony at the hearing.

4. Witnesses

The following witnesses will address the subcommittee:

Mr. Robert Shea, Acting Administrator Federal Insurance and Mitigation Administration, and, Mr. Craig Wingo, Director of Division of Engineering Science and Technology, Federal Emergency Management Administration

Dr. W. Gene Corley, P.E., S.E., American Society of Civil Engineers, Chair of the Building Performance Assessment Team reviewing the WTC disaster

Professor Glenn Corbett, Assistant Professor of Fire Science at John Jay College, New York City

Dr. Abolhassan Astaneh-Asl, Professor, Department of Civil and Environmental Engineering University of California, Berkeley

Dr. Arden Bement, Director, National Institute of Standards and Technology

5. Additional Reading

Glanz, J. (2001, December 4). Wounded Buildings Offer Survival Lessons. The New York Times, p. F1

Glanz, J., & Lipton, E. (2001, December 25). A National Challenged: The Towers; Experts Urging Broader Inquiry in Towers' Fall. The New York Times, p. A1

Glanz, J., & Lipton, E. (2002, January 17). New Agency to Investigate the Collapse of Towers. The New York Times, p. B3

Glanz, J., & Lipton, E. (2002, February 2). At Scrapyards, as Search for Clues in the Towers' Collapse. The New York Times, p. B1

Appendix A
Letters and Questions to Witnesses:

February 20, 2002

Mr. Joe Allbaugh, Director
Federal Emergency Management Agency
500 C Street, S.W.
Washington, D.C. 20472

Dear Mr. Allbaugh:

The Science Committee of the U.S. House of Representatives will hold a hearing entitled "Learning from 9/11: Understanding the Collapse of the World Trade Center" on February 26, 2002 at 2:30 PM in 2175 of the Rayburn House Office Building. I would like to request your presence, or that of your designee, to testify at this hearing.

The Committee's hearing will focus on understanding the nature of the post-disaster reconnaissance response to the World Trade Center (WTC) attacks. Your verbal testimony should address the following questions:

- Describe FEMA's role in investigating the collapse with particular attention to answering these questions: (1) What has FEMA done to ensure that a range of researchers have had access to the WTC site? (2) Have conflicts arisen between the BPAT and other researchers and how has FEMA responded?
- What effects have impediments such as the loss of materials from the site and the delay in obtaining access to the blueprints for the World Trade Center buildings had on the progress of the investigation? How has FEMA responded to these impediments?
- Should the protocols for investigations such as these be changed in order to deal with similar impediments in the future? If so, what changes would FEMA recommend?
- Does FEMA have policies in place to govern its cooperation with other Federal agencies in the wake of building failures? How did FEMA decide what role agencies like NIST and NSF should play at the world trade center?
- Has the confidential nature of the BPAT investigation made it more difficult to gain access to materials that might be useful in the investigation, such as private videotapes?

In order to allow sufficient time for questions at the hearing, you should highlight the most significant points of your testimony in an oral presentation of no more than five minutes. Your written statement may be as extensive as you wish and will be included in the hearing record in its entirety. Oral statements and answers to questions will be printed as part of the verbatim record of the hearing; only transcription errors will be edited.

Witnesses testifying before the Committee on Science must observe procedures governing witness testimony. Please see the attached one page description of these requirements and note the timing required for materials submission. Regarding the hardcopies of testimony requested, we encourage you to attach your biography at the back of your testimony, double side your copies when possible to conserve paper, and submit these documents as early as possible.

Materials that may be E-mailed or sent by facsimile may be sent to (b)(6) @mail.house.gov or faxed to her attention at (b)(6) Please call (b)(6) at (b)(6) o discuss delivery of hard copies of testimony.

In addition, if you wish to use the Committee's multimedia facilities, a description of which I've enclosed, please contact (b)(6) at (b)(6) My staff can usually accommodate most requests with 72 hours notice.

If you have any questions concerning your appearance before the Committee on Science, please contact (b)(6) of the Committee staff at (b)(6) and (b)(6) respectively. I look forward to your participation in the hearing.

Sincerely,

Sherwood L. Boehlert
Chairman
House Science Committee

February 19, 2002

Dr. W. Gene Corley
Senior Vice President
Construction Technologies Laboratories
c/o American Society of Civil Engineers
1015 15th Street, N.W.
Suite 600
Washington, D.C. 20005-2605

Dear Dr. Corely:

The Science Committee of the U.S. House of Representatives will hold a hearing entitled "Learning from 9/11: Understanding the Collapse of the World Trade Center" on February 26, 2002 at 2:30 PM in 2175 of the Rayburn House Office Building. I would like to request your presence to testify at this hearing.

The Committee's hearing will focus on understanding the nature of the post-disaster reconnaissance response to the World Trade Center (WTC) attacks. Your verbal testimony should address the following questions:

- What role did your society play in investigating the collapse of the WTC buildings, and what is the timeline of your review?
- Please describe the impediments your team encountered during the investigation of the collapse of the WTC buildings, such as the loss of material from the WTC site and any effects of such impediments on the report that your team is preparing.
- Should the Federal Emergency Management Agency (FEMA) and/or Congress develop a more comprehensive protocol for how to conduct investigations in response to natural disasters and/or terrorist attacks?
- How can the efforts to determine the exact sequence of events that led to a progressive collapse of the buildings be used to improve building practices, standards, and codes?

In order to allow sufficient time for questions at the hearing, you should highlight the most significant points of your testimony in an oral presentation of no more than five minutes. Your written statement may be as extensive as you wish and will be included in the hearing record in its entirety. Oral statements and answers to questions will be printed as part of the verbatim record of the hearing; only transcription errors will be edited.

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If you have any questions concerning your appearance before the Committee on Science, please contact (b)(6) of the Committee staff at (b)(6) and (b)(6) respectively. I look forward to your participation in the hearing.

Sincerely,

Sherwood L. Boehlert
Chairman
House Science Committee

February 20, 2002

Mr. Glenn P. Corbett
Assistant Professor of Fire Science
Department of Public Management
John Jay College of Criminal Justice
445 West 59th Street
New York, New York 10019

Dear Mr. Corbett:

The Science Committee of the U.S. House of Representatives will hold a hearing entitled "Learning from 9/11: Understanding the Collapse of the World Trade Center" on February 26, 2002 at 2:30 PM in 2175 of the Rayburn House Office Building. I would like to request your presence to testify at this hearing.

The Committee's hearing will focus on understanding the nature of the post-disaster reconnaissance response to the World Trade Center (WTC) attacks. Your verbal testimony should address the following questions:

- What effects have the loss of materials from the site and the delay in obtaining access to the blueprints for the World Trade Center buildings had on the progress of the investigation?
- Should the Federal Emergency Management Agency (FEMA) and/or Congress develop a more comprehensive protocol for how investigations in response to natural disasters and/or terrorist attacks are conducted, and, if so, what should such a protocol look like?
- What areas of research into the WTC collapse still need to be addressed, and what is the most appropriate way to handle these needs? What are the gaps in our understanding of how fire affects building materials and design, and how can we best fill those gaps?
- Given what we have learned to date about the cause of the collapse of the World Trade Center Buildings, should building practices, standards, and codes be improved? If so, how should the results of the investigations into the collapse of the building be used to improve them?

In order to allow sufficient time for questions at the hearing, you should highlight the most significant points of your testimony in an oral presentation of no more than five minutes. Your written statement may be as extensive as you wish and will be included in the hearing record in its entirety. Oral statements and answers to questions will be printed as part of the verbatim record of the hearing; only transcription errors will be edited.

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If you have any questions concerning your appearance before the Committee on Science, please contact (b)(6) of the Committee staff at (b)(6) and (b)(6) respectively. I look forward to your participation in the hearing.

Sincerely,

Sherwood L. Boehlert
Chairman
House Science Committee

February 28, 2002

Abolhassan Astaneh-Asl, Ph.D.
Professor
Department of Civil and Environmental Engineering
University of California, Berkeley
Berkeley, CA 94720-1710

Dear Dr. Astaneh-Asl:

The Science Committee of the U.S. House of Representatives will hold a hearing entitled "Learning from 9/11: Understanding the Collapse of the World Trade Center" on March 6, 2002 at 12:00 PM in 2318 of the Rayburn House Office Building. I would like to request your presence to testify at this hearing.

The Committee's hearing will focus on understanding the nature of the post-disaster reconnaissance response to the World Trade Center (WTC) attacks. Your verbal testimony should address the following questions:

- What role did you play in the investigating the collapse of the WTC buildings and what do you expect to produce from your effort? How did you arrange NSF funding for your work, and how was that arranged so quickly?
- Please describe the impediments that you encountered during the investigation of the collapse of the WTC buildings, such as the loss of material from the WTC site and any effects of such impediments on your work.
- Should the Federal Emergency Management Agency (FEMA) and/or Congress develop a more comprehensive protocol for how to conduct investigations in response to natural disasters and/or terrorist attacks?
- What areas of research into the WTC collapse still need to be addressed, and what is the most appropriate way to handle these needs?
- Has the confidential nature of the FEMA's Building Performance Assessment Team investigation made it more difficult to gain access to materials that might be useful, such as private videotapes?

In order to allow sufficient time for questions at the hearing, you should highlight the most significant points of your testimony in an oral presentation of no more than five minutes. Your written statement may be as extensive as you wish and will be included in the hearing record in its entirety. Oral statements and answers to questions will be printed as part of the verbatim record of the hearing; only transcription errors will be edited.

Witnesses testifying before the Committee on Science must observe procedures governing witness testimony. Please see the attached one page description of these requirements and note the timing required for materials submission. Regarding the hardcopies of testimony requested, we encourage you to attach your biography at the back of your testimony, double side your copies when possible to conserve paper, and submit these documents as early as possible. Please also remember to send us a letter of financial disclosure, as outlined in the attached document.

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If you have any questions concerning your appearance before the Committee on Science, please contact (b)(6) of the Committee staff at (b)(6) and (b)(6) respectively. I look forward to your participation in the hearing.

Sincerely,

Sherwood L. Boehlert
Chairman
House Science Committee

February 20, 2002

Dr. Arden L. Bement, Jr.
Director
National Institute of Standards and Technology
100 Bureau Drive
Stop 1000
Gaithersburg, MD 20899

Dear Dr. Bement:

The Science Committee of the U.S. House of Representatives will hold a hearing entitled "Learning from 9/11: Understanding the Collapse of the World Trade Center" on February 26, 2002 at 2:30 PM in 2175 of the Rayburn House Office Building. I would like to request your presence to testify at this hearing.

The Committee's hearing will focus on understanding the nature of the post-disaster reconnaissance response to the World Trade Center (WTC) attacks. Your verbal testimony should address the following questions:

- What does National Institute of Standards and Technology (NIST) see as its role in the investigation of building collapses, and is this role codified in any document or agreement?
- What role did it play before being asked by the Federal Emergency Management Agency (FEMA) to take over the investigation of the collapse of the WTC buildings? Why hadn't NIST played a larger role previously?
- What are the goals of NIST's new investigation and what specific steps will it take to meet them? To what extent will the loss of material from the site hinder to the new investigation?
- How can our efforts to determine the exact sequence of events that led to a progressive collapse of the buildings be used to improve building practices, standards, and codes?
- What are the gaps in our understanding of how fire affects building materials and design, and what needs to be done to fill those gaps?

In order to allow sufficient time for questions at the hearing, you should highlight the most significant points of your testimony in an oral presentation of no more than five minutes. Your written statement may be as extensive as you wish and will be included in the hearing record in its entirety. Oral statements and answers to questions will be printed as part of the verbatim record of the hearing; only transcription errors will be edited.

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Sincerely,

Sherwood L. Boehlert
Chairman
House Science Committee

Appendix B

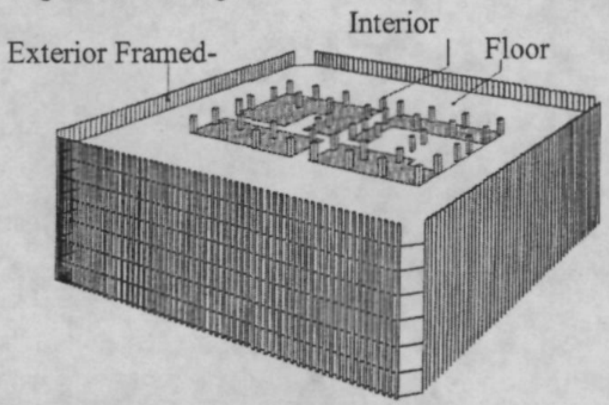
NSF Small Grants for Exploratory Research Awards made in response to the events of September 11, 2001.

- $100,000 to the Multidisciplinary Center for Earthquake Engineering Research at SUNY Buffalo (in partnerships with the University of Delaware) to conduct structural analysis of damaged but standing buildings and to conduct social science research of human response in the context of disasters;
- $45,000 to the University of Florida (in partnership with NOAA) to assess infrastructure damage utilizing land-based laser swath mapping technology;
- $20,000 to Georgia Tech to develop digital data collection technology for damage assessment;
- $15,000 to University of California Berkeley to conduct post-disaster structural engineering data collection;
- $15,000 to University of Maryland to conduct fire analysis at the WTC site;
- $25,000 to George Washington University to observe and document the inter-organizational response to the terror attacks (and later the anthrax dispersal);
- $70,000 to Rennesalear Polytechnic Institute for research on critical infrastructure interdependence; and
- $10,000 to University of Colorado Boulder to provide support to a number of social scientists associated with the Natural Hazards Research Application and Information Center

Appendix C
Building Design and Collapse Scenarios

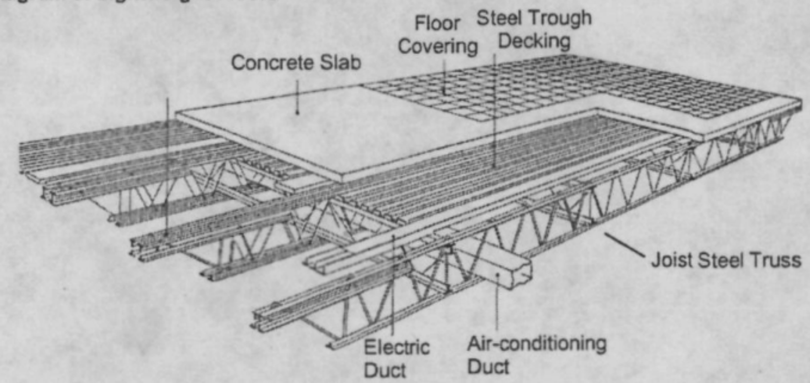
The World Trade Center towers were designed and constructed in the late 1960s using what were considered groundbreaking design and construction methods at the time. Most high-rise buildings, such at the Empire State Building, were designed using a skeleton frame structure of welded or riveted steel columns and beams, often encased in concrete. In this design, the columns carry the load of the building while the external wall carries little, if any, of the loads.

Diagram of WTC Design



To reach the spectacular heights that the World Trade Center architects envisioned, the engineers came up with a radically different design frequently called a "tube" structure. The key to this design lay in the use of closely spaced high-strength vertical steel columns connected by horizontal beams along the outer faces of the building. This matrix constituted a rigid, but flexible outer tube structure designed to resist the forces from the high winds that plague tall buildings in New York City. The design also consisted of a massive hollow internal steel column that supported most of the gravity load of the building, in addition to housing the stairwells, elevator shafts, and bathrooms. The final element were the lightweight floors, which connected the internal and external parts of the building and each typically consisted of four inches of concrete poured over steel decking and laid upon lightweight steel trusses. The trusses were attached to steel seats at both the interior and exterior columns. This revolutionary design not only allowed the building to withstand high winds and reach a previously unattainable 110 stories, but it also allowed for large open-spaced floors – providing a total of about 10 million square feet of commercial space in the two buildings.

Diagram of Lightweight Floors



The research community is actively exploring three predominate hypotheses as to the exact sequence of events that led to the progressive collapse of the towers. The first hypothesis is that fire weakened the floor trusses that connected the exterior and interior columns, causing the trusses to sag and eventually separate from the external walls. The external columns, without the trusses to provide lateral restraint, then buckled and caused the buildings to collapse. The second hypothesis is that initial impact of the planes was so great the towers were on the verge of collapsing when the fire weakened the external columns, causing them to buckle and collapse. The third hypothesis is that the initial impact caused the weight of the upper floors of the building to be shifted from the exterior to the interior columns (through trusses on top of the towers). The overload damaged the interior columns, which failed and caused the building to collapse.

Testimony of

Dr. Abolhassan Astaneh-Asl
Professor
Department of Civil and Environmental Engineering
University of California, Berkeley

Before the Committee on Science of the U.S. House of Representatives

March 6, 2002 Hearing on

"Learning from 9/11: Understanding the Collapse of the World Trade Center"

It is a great honor for me to testify here today and address specific questions listed in your letter (in *Italic below)* regarding my involvement in the post disaster investigation of the World Trade Center.

- *What role did you play in the investigating the collapse of the WTC buildings and what do you expect to produce from your effort? How did you arrange NSF funding for your work, and how was that arranged so quickly?*

My involvement in the investigation of the collapse of the World Trade Center is to conduct a reconnaissance of the collapsed and damaged WTC buildings and to collect the perishable data. The main objectives of the reconnaissance are to learn as much as possible from the actual collapsed structures and to document the failure modes and performance of the members and connections as well as quality of the construction. The purpose of collecting the perishable data is to collect material samples, photographs, videotapes, drawings and data on design, construction and collapse. Using the information collected and by conducting the necessary analyses and research, we try to establish probable causes of the collapse and most likely scenario for such collapse.

Our project was funded by the Directorate of Engineering of the National Science Foundation as one of the eight Quick Response Research Awards in the aftermath of the WTC collapse. These projects focus on structural engineering (our project at UC-Berkeley), fire engineering, social aspects and response and recovery. More information on these projects can be found at www.nsf.gov. We prepared and submitted our proposal to the National Science Foundation three days after the 9/11 events and it was reviewed and funded by the end of the week. The credit for such a fast preparation, submittal, review and funding of these research projects should be given equally to the staff at the universities involved as well as the Program Directors and staff of the National Science Foundation. The use of "Fastlane" electronic submittal process of the NSF also expedited the process tremendously.

So far, I have made three trips to NYC and spent a total of about 25 days there conducting field investigation and collecting data. Upon arrival to NYC on September 19, and after visiting Ground Zero and paying my respects and prayers to the victims, I started my reconnaissance and collection of the perishable data. I have collected some data on design and construction of the WTC and have met and discussed the case with the structural engineers who have designed the WTC Buildings. Thanks to cooperation of the HSNE recycling plant, I have been able to study the steel from the WTC before recycling. I have identified and saved some components of the structures that appear to have been subjected to intense fire or impact of fast moving objects. Figures 1 through 4 show examples of inspected structures. These critical pieces are saved as perishable data and can be used in future research.

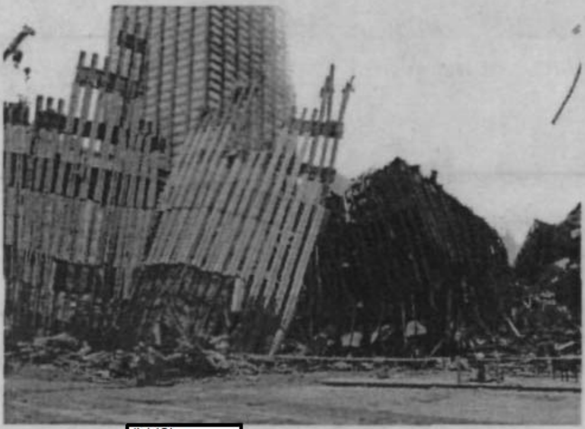


Photo by (b)(6) for A. Astaneh's NSF Report

Fig. 1. Collapsed exterior walls of WTC towers

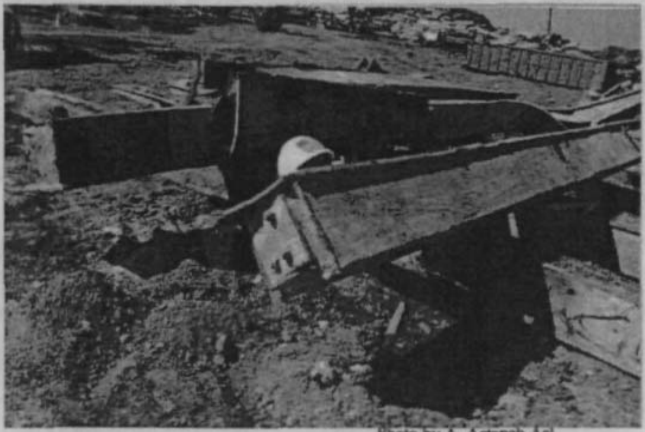


Photo by A. Astaneh-Asl

Fig. 2. A critical connection of exterior columns of WTC

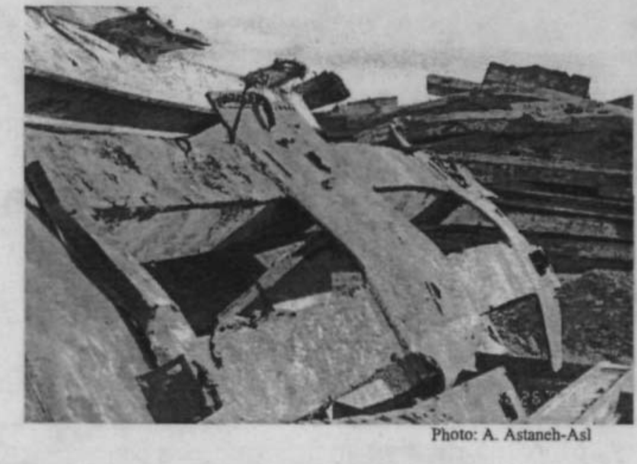


Photo: A. Astaneh-Asl

Fig. 3. Exterior columns of WTC towers probably buckled after being subjected to intense heat.

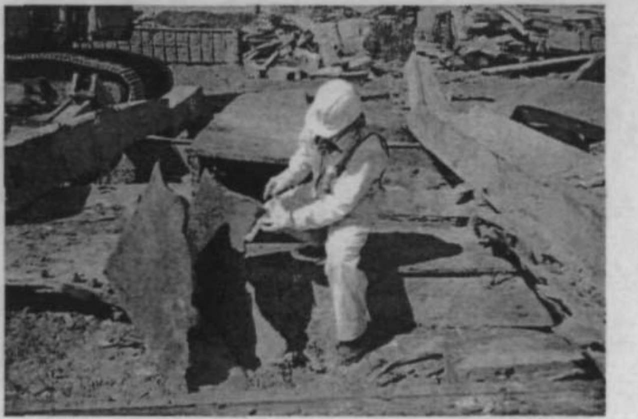


Photo: HNSE

Fig. 4. A. Astaneh inspecting an internal column of WTC which has been hit with a round object

- *Please describe the impediments that you encountered during the investigation of the collapse of the WTC buildings, such as the loss of material from the WTC site and any effects of such impediments on your work.*

I wish I had more time to inspect steel structure and save more pieces before the steel was recycled. However, given the fact that other teams such as NIST, SEAONY and FEMA-BPAT have also done inspection and have collected the perishable data, it seems to me that collectively we may have been able to collect sufficient data. The main impediments to my work were and still are:

1. Not having a copy of the engineering drawings and design and construction documents.
2. Not having copies of the photographs and videotapes that various agencies might have taken during and immediately after the collapse.

Such data has already been made available to ASCE Building Performance Assessment Team. If those are also available to us, we will be able to proceed further with our research. Figure 5 shows an example of analysis of performance of generic steel high-rise structure subjected to the impact of a 747 jetliner and the ensuing fire. The example demonstrates the power of advanced technology developed in aerospace and mechanical engineering that can be brought to bear on this problem. We plan to use the drawings and the data and the software used in the example to build a computer based realistic model of the World Trade Center towers and analyze their response to simulated impact of the 767 planes that crashed into them on 9/11 and the ensuing fire.

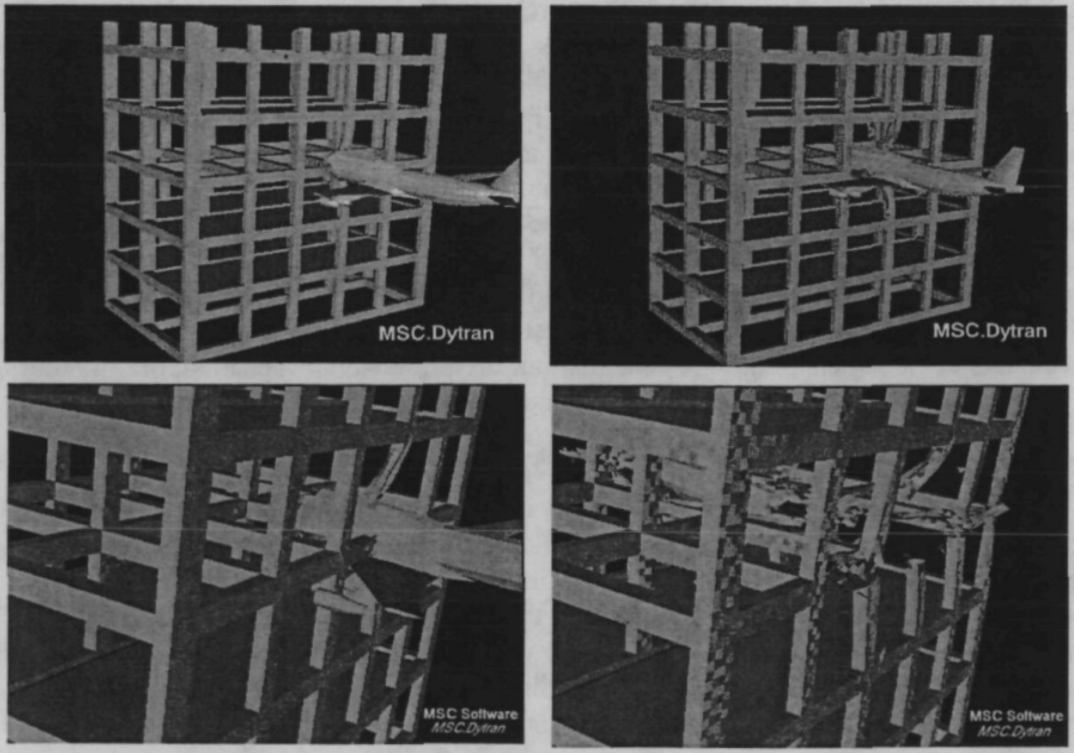


Fig. 5. Results of simulation analysis of impact of a 747 jetliner crashing into a steel structure. Notice fracture of the steel column and breaking of the plane due to dynamic stresses (Graphics and analysis by MSC Software Corporation)

- *should the Federal Emergency Management Agency (FEMA) and/or Congress develops a more comprehensive protocol for how to conduct investigations in response to natural disasters and/or terrorist attacks?*

The earthquake engineering community has conducted post disaster investigations very successfully and systematically within the Earthquake Engineering Research Institute and funded by NSF and FEMA for several decades. As a result of such post-disaster investigations, the lessons learned and the continued research and technology developments, great advances have been made in mitigating earthquake hazard. The approach taken in earthquake engineering can equally be applied to investigation of damage due to terrorist attacks as well as to minimizing consequences of such attacks. Due to criminal nature of terrorist attacks and higher priority placed on criminal investigation over engineering investigation, it appears that there is a need for a protocol to govern the availability of information and access to the site as well as interaction of the crime investigators and researchers investigating the scientific and engineering aspects of the terrorist attacks.

- *what areas of research into the WTC collapse still need to be addressed, and what is the most appropriate way to handle these needs?*

There are short term and long-term research needs into the WTC collapse. In short term, there is a need for a comprehensive, in-depth and research-oriented study of the WTC buildings from the time of plane impact, through the ensuing fire and the final collapse. Such studies not only should focus on structural and fire engineering aspects, but also social and human aspects of the tragedy as well. A broad based team of researchers and engineers from academia, government agencies and private sector, with expertise in various aspects of the problem need to be assembled to conduct such studies. In my opinion, such studies need to be directed by federal entities such as National Science Foundation (NSF) and/or National Institute of Standards and Technology (NIST) that are involved in directing and conducting scientific and engineering research. In December, the National Science Foundation sponsored a workshops organized by the Institute for Civil Infrastructure Systems of the New York University to identify research needs for future research related to WTC. A list of workshop recommendations can be found at www.nsf.gov. I participated at the workshop and feel that funding research in those areas will result in learning many valuable lessons from this tragedy and will result in significant improvements in the structural design, construction, fire protection, evacuation, fire fighting, rescue and recovery efforts, debris removal and many other aspects of protection of buildings and occupants against terrorist attacks.

In the long term, there is a need for major and sustained funding to conduct basic and applied research on various aspects of terrorist attacks. Such research activities can result in development of scientific methods and technologies to assure life safety, prevent catastrophic collapses and massive loss of lives and minimize the impact of such attacks on the national economy and security. Last months, NIST held a workshop to identify research needs related to evaluation of performance and protection of buildings during intense fires. I also participated at this workshop and feel that the research areas identified at the workshop are very important in providing engineers and architects with the technologies to protect tall buildings, their occupants and firefighter and rescuers against catastrophic fires and resulting collapse.

In the aftermath of 9/11 tragedy and the hazard posed by terrorist attacks to public safety and the economical well being of the U.S. is not much different than the hazard posed by other "extreme events' such as major earthquakes three or four decades ago. In the case of seismic hazard mitigation, Congress, by providing sufficient funding to the National Science Foundation and other agencies involved, has enabled research and engineering community to develop efficient and economical technologies to mitigate seismic hazard and to prevent catastrophic loss of lives. To prevent catastrophic consequences of terrorist attacks, we need to develop and fund a long-term plan of research, perhaps modeled after seismic research programs developed and supported over the years by NSF and FEMA, and in the field of protection of built environment against terrorist attacks.

- *has the confidential nature of the FEMA's Building Performance Assessment Team investigation made it more difficult to gain access to materials that might be useful, such as private videotapes?*

I have not been provided with the information made available to the FEMA Building Performance Assessment Team. This includes, videotapes and photographs taken on 9/11and the following days and copies of the engineering drawings. At this time, having the videotapes, photographs and copies of the drawings not only is useful, but also is *essential* in enabling us to conduct any analysis of the collapse and to formulate conclusions from our effort.

I have been the Principal Investigator in conducting research on damage and collapse of several major buildings and bridges in the aftermath of earthquakes. I understand and respect the concerns of owners, designers, builders and those who are responsible for safe operation of these structures for possible legal ramifications of findings of our research investigations. However, the main objective of our research is to understand how the WTC buildings failed and learn lessons that can be used to prevent such collapses in the future. Never before my research results have been used in any legal proceedings. However, to allay any concerns that any findings of our research project might increase the liabilities of the City, Port Authority or Silverstein, the data on these structures could be provided to the Principal Investigator (myself) on a propriety basis. The Principal Investigator would keep the data and provide the other members of the research team with the information on a need-to-know basis. I have followed similar procedures to the satisfaction of parties involved in conducting research on major buildings and bridges subjected to earthquakes and blasts due to terrorist attacks.

I would like to take this opportunity and thank Chairman Boehlert and members of the Committee on Science for inviting me to testify. I would like now to welcome any questions that you may have.

(b)(6)

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EDUCATION: M.S.E. (b)(6) and Ph.D. (b)(6) from the University of Michigan, Ann Arbor

CURRENT POSITION: Professor, University of California at Berkeley.

PROFESSIONAL MEMBERSHIP: American Society of Civil Engineers (ASCE), Council on Tall Buildings and Urban Habitat (CTBUH), Earthquake Engineering Research Institute (EERI), Structural Stability Research Council (SSRC), Research Council on Structural Connections (RCSC), Consortium of Universities for Research in Earthquake Engineering (CUREE), Advisory Committee AC4 and Technical Committee TC8 of Eurocode Europe, Structural Engineers Association of Northern California, (SEAONC), Structural Steel Educational Council, (SSEC), Committee on Design of Blast-Resistant Steel Structures (AISC)

PROFESSIONAL REGISTRATION: Registered Professional Engineer, P.E. (California)

MAJOR AWARD: Winner of 1998 ,T.R. Higgins Award, American Institute of Steel Construction

TEACHING: Has taught courses since 1982 on Engineering Mechanics, Static, Design of Steel Structures, Advanced Steel Design, Design of Steel and Composite Structures, Inelastic Behavior and Plastic Design of Steel Structures, Comprehensive Design of Structures. He has also taught a number of short courses to professionals on design of structures and earthquake engineering particularly on bridges to Caltrans engineers and others.

MAJOR RESEARCH & DEVELOPMENT PROJECTS DURING LAST 5 YEARS:

1. "Tests of Critical members of the Golden Gate Bridge", (Funded by Golden gate Bridge), 95-96
2. "Shake-table Tests of Computers with and without Support Restrainers", 96-97.
3. "Cyclic Behavior and Seismic Design of Steel Piles", (Funded by Caltrans), 96-98.
4. "Nonlinear Analyses of the Suspension Spans of the Bay Bridge", (Funded by LLNL & UCB, 95-98.
5. "Seismic Behavior and Design of Shear Connections", (Funded by FEMA/SAC), 97-98.
6. "Cyclic Tests and Seismic Design Provisions for Steel Shear Walls", (Funded by GSA),99-01.
7. "Cyclic Tests of Traditional and Innovative Composite Shear Walls", (Funded by NSF) 98-present.
8. "Testing and Studying Blast-Resistant Structures", (Funded by GSA and AISC) 97-present.
9. "Studies of Collapse of the World Trade Center",(Funded by NSF) ,01-present

PUBLICATIONS

Has published more than 150 papers, reports and other publications on the behavior and design of steel structures subjected to seismic, gravity and blast loads.

Statement of

Professor Glenn P. Corbett
John Jay College of Criminal Justice

Before the

Committee on Science
House of Representatives
United States Congress

"Learning From 9/11: Understanding the Collapse of the World Trade Center"

March 6, 2002

Good afternoon Chairman Boehlert and Members of the House Committee on Science. I want to thank you for inviting me to speak on the topic of the World Trade Center disaster investigation. This is an issue of national importance, and I speak for many who understand that importance.

I would like to discuss three issues with you today: an analysis of the current building performance assessment study of the World Trade Center collapse, a proposal for a national disaster investigation response protocol for future disasters, and a recommendation for a *Commission on the World Trade Center Disaster.*

In the wake of the loss of the World Trade Center, many questions began to arise as to the cause of the collapse of the twin towers. We know, of course, that the towers collapsed catastrophically in a very short time. We know that there is no precedent for this event. And we in the fire protection engineering community know that building failures result directly from very specific causal factors and structural behavioral characteristics that, in the case of the WTC, have yet to be determined.

What role did the planes play in destroying the structural integrity of the towers? What was the impact of the jet fuel fires upon the steel trusses and columns? How long did the jet fuel fires burn? What were the specific causal factors of collapse and what was the exact sequence of events that led to the collapse?

These are important questions that impact national security. We are a nation at risk. There are many high-rise structures in the United States—and more on the way—that demand that we learn from the disaster on 9-11 and apply the lessons learned.

As engineers, as architects, as builders, as firefighters, as citizens who occupy high-rises, and as those who are in a position to protect those citizens, there are critical questions regarding this collapse that need answering. We must extract the lessons for future generations who will live and work in high-rise structures.

The building performance assessment currently being conducted of the World Trade Center collapse is just that: an assessment, not an investigation. While the Building Performance Assessment Team (BPAT) is composed of an elite group of engineers and scientists, the standard procedures used by the BPAT have proven to be inadequate. Handling the collapse study as an assessment has allowed valuable evidence—the steel building components—to be destroyed. The steel holds the primary key to understanding the chronology of events and causal factors resulting in the collapse.

Without an *investigative* presence, the FEMA-sanctioned assessment team did not have the authority—nor the organizational wherewithal—to ensure that *all* of the structural steel was thoroughly examined and the crucial steel from the points of impact saved for examination. Only a handful of pieces of steel from the points of impact have been secured to date. In addition, the BPAT studying the collapse has apparently been hampered in accessing building construction documents.

These hindrances will have an impact on the BPAT report, due to be released in April. The lack of significant amounts of steel for examination will make it difficult, if not impossible, to make a definitive statement as to the *specific* cause and chronology of the collapse.

The collapse of the World Trade Center towers were the largest structural collapses in world history. A disaster of such epic proportions demands that we fully resource a comprehensive, detailed investigation. Instead, we are staffing the BPAT with part-time engineers and scientists on a shoestring budget.

The current World Trade Center disaster inquiry has exposed a gaping hole in the way that we investigate disasters. We don't have a *comprehensive* plan for disaster investigations (other than plane crashes) and we don't apply the necessary resources for complete and thorough investigations of disasters.

We must have a comprehensive plan in place to handle such large-scale investigations. We need to have a greatly enhanced national disaster investigation response protocol, providing for a systematic approach. We must bring in the experts in a rapid, organized manner to extract *all* of the lessons from a disaster. Finally, and most importantly, we need to ensure that the lessons are actually applied.

I recommend that a task force be impaneled to develop such a protocol. In my opinion, FEMA would be the best organization to organize the task force, given their role in disaster response and their critical disaster mitigation responsibilities. ***[Witness would like to submit, for the record, a document entitled Appendix A "PROPOSAL FOR AN ENHANCED DISASTER INVESTIGATION PROTOCOL"]***

The collapses of the World Trade Center structures are not the only areas of concern. There are five other very important areas of study concerning the World Trade Center disaster need to be explored. In addition to the collapse study, we should be analyzing the building designs themselves, the firefighting procedures, the building evacuations, the search and rescue operations, and the impact on building and fire codes.

These six primary focus areas would form the basis of a complete World Trade Center study. Since these focus areas are multi-disciplinary, it is critical that the experts in each of these areas be permitted to come together under one roof, so to speak. This will ensure coordination, avoid duplication, verify that all areas of concern are covered, and ensure that the essential process of information sharing takes place.

The World Trade Center disaster must be analyzed as a total event, using an integrated, scientifically rigorous approach. Studying the issues individually minimizes the effect on the whole. There are interrelationships among these areas that must be combined and the lessons applied for future generations.

I recommend that a *World Trade Center Disaster Commission* be immediately organized to initiate a comprehensive investigation and to coordinate the existing public and private World Trade Center research projects currently underway. For example, an ad hoc committee entitled the *World Trade Center Evacuation Study Initiative* (composed of life safety experts from many different organizations) has been meeting for several months to study the issues of the World Trade Center building evacuations. It is important that this group and other World Trade Center research projects come together to allow for a coordinated approach to studying this disaster.

The *Commission* should be given the appropriate authority and staff to ensure that a viable investigation plan is created and implemented, with the ultimate goal of producing a comprehensive report that details the findings of the investigation, the "lessons learned," and, finally, the "needs for further research."

Some of the lessons that will emerge in the *Commission* report will apply directly to our building codes and the way that we build new structures. Of particular importance are the regulations covering fire protection of high-rise buildings. ***[Witness would like to***

submit, for the record, a document entitled Appendix B "PROPOSAL FOR A WORLD TRADE CENTER DISASTER COMMISSION]

Our current high-rise code requirements do not address the real world issues encountered when fighting fires in high-rise buildings. For example, our model building codes treat a 15-story building exactly the same as a 100-story building in terms of fire protection—we apply the same level of structural fire resistance, the same fire protection systems, the same everything. We place heavy reliance on automatic sprinkler systems, with little redundancy in terms of structural fire resistance to ensure that the building will stay up long enough to allow for firefighters to reach the fire area, rescue trapped inhabitants, and generally deal with the situation. Automatic sprinklers are *the* best protection against fire, but we need to have a backup when we are 1,000 feet high in a building on fire. We need a proper balance of passive and active protection in larger high-rise structures.

An example of the crucial need for research is found when we analyze the current test used to establish the fire resistance various structural members used in buildings. This test, commonly known as A.S.T.M. E-119, was developed to provide assurance that the fire protection coating/encasement provided for beams and columns would allow them to be subjected to high temperatures and not collapse. This test, however, dates back to the 1920's and is based upon the temperatures recorded when a set of buildings were burned back then for study purposes. Today, we basically still use the same test with the same "fire" temperature and exposure conditions developed over 75 years ago. I would argue that the fires of the 1920's are different than those of today, and that this nationally accepted test needs to be thoroughly reexamined in light of what happened on 9-11.

We can learn many lessons from the disaster at the World Trade Center. In fact, we *must* learn these lessons. The lessons may take the form of better building code regulations, enhanced building design methodologies, improved emergency procedures, and enhanced protection against terrorist attacks. We must assure that these lessons are actually applied, thus improving the level of safety and security for American citizens.

I thank you, Congressman Boehlert and honorable members of the Science Committee, for giving me the opportunity to share my thoughts with you. I would be happy to answer any questions that you may have.

Appendix A

PROPOSAL FOR AN ENHANCED DISASTER INVESTIGATION PROTOCOL

Prepared by Professor Glenn P. Corbett
John Jay College of Criminal Justice

Need for an Enhanced Protocol:

When a major disaster strikes in the United States, very important questions typically arise: What happened? Why were so many lives lost? How can we prevent this from happening in the future?

These questions need answers. If we are to protect ourselves and future generations, we must learn the lessons of the disaster and apply them

For past disasters like the Oklahoma City bombing and the Northridge earthquake, a variety of research projects were undertaken. While these research projects produced very useful information, they were conducted independently, without the benefit of a central coordinating body to integrate all of the information. In addition, it has become apparent that some of the very critical lessons never found their way into general design practice – there is a disconnect between the private sector code-writing organizations and the lessons coming out of the research projects .

Since disasters are multi-disciplinary, they require an integrated and comprehensive approach. The disaster must be investigated as a whole, following standard investigative procedures. A single standardized model can be developed for all disasters, with a specific set of "adaptable" procedures for each type of disaster.

Development of an Enhanced Disaster Investigation Protocol

Since FEMA has responsibilities for disaster response and disaster mitigation, it is suggested that the development of an enhanced disaster investigation protocol be initiated within FEMA. Other Federal agencies and private sector organizations with disaster responsibilities/interest would obviously need to participate in the development of the protocol. The National Transportation Safety Board's investigation procedures provide a very useful model for which to begin the development of an enhanced disaster investigation protocol.

"Organizational" Details of a Enhanced Disaster Investigation Protocol

Organizationally, an enhanced disaster investigation protocol:

- Utilizes an *investigative* "lessons learned" approach to analyzing disasters.
- Provides a detailed investigation "command structure" to establish which agency is in charge and the limits of its investigative authority.
- Details the responsibilities of each participating organization.
- Establishes the specific types of disasters that will be investigated and the necessary resources needed for each type of disaster.

"Functional" Details of an Enhanced Disaster Investigation Protocol

Functionally, an enhanced disaster investigation protocol:

- Incorporates a "rapid response" capability, allowing for the immediate deployment of a initial set of investigators to plan the investigation, secure evidence, and to begin the documentation process.
- Ensures the deployment of self-sufficient, disaster-specific "specialist teams" to the scene to conduct the detailed investigation work (similar to USAR organization).
- Ensure that periodic press releases are issued to inform the public of the investigation and its progress.

"Coordination" Details of an Enhanced Disaster Investigation Protocol

In order to assure coordination, an enhanced disaster investigation protocol:

- Ensures that liaisons are appointed to the local incident commander's command post, search and rescue teams (e.g. USAR), and criminal investigation organizations (e.g. FBI) to ensure coordination with their efforts.
- Ensures that the appropriate "specialist teams" are deployed and are working together efficiently.
- Ensures that additional "outside" research efforts are integrated into the investigation.
- Ensures that a regimented set of meetings with specialist team leaders and staff are held to review progress and to keep investigation on course.

"Final Report" Details of an Enhanced Disaster Investigation Protocol

In order to produce a comprehensive report, an enhanced disaster investigation protocol:

- Ensures that the specialist team leaders are assembled to provide oral presentations to other team leaders/staff and to provide written draft reports for inclusion in Final Report.
- Ensures that the staff support collates the team reports and configures them into a standardized, "single author" report format.
- Ensures that long-term research needs are identified and documented for inclusion in the Final Report.

"Applied Lessons" Details of an Enhanced Disaster Investigation Protocol

To ensure the application of the "lessons learned," an enhanced investigation protocol:

- Appoints code-writing organization representatives to investigative "specialist teams."
- Establishes a "formal agreement" with the private sector code-writing bodies that ensures every recommendation for a change in the codes will be formally reviewed by the code-writing body. Final disposition of "disaster" code change proposals (including rationale if code change is rejected) will be formally documented and issued back to the affected disaster investigation organizations.

Appendix B

PROPOSAL FOR A WORLD TRADE CENTER DISASTER COMMISSION

Prepared by Professor Glenn P. Corbett
John Jay College of Criminal Justice

Need for the Commission:

In the wake of the World Trade Center disaster, it has become readily apparent that many issues involving high-rise building construction, emergency evacuation procedures, firefighting operations, and other important concerns must be analyzed collectively in order to learn from the disaster and apply the lessons to the future. Many Americans live and work in high-rise buildings, so it is essential that we learn as much as possible about this disaster.

The establishment of a Commission will allow for the various public and private research efforts currently underway to come together "under one roof" and share information, a critical issue when studying a disaster as complex as the collapse of the World Trade Center towers. The multi-disciplinary aspects of the World Trade Center necessitate that the disaster be investigated in that context, allowing for the identification of interrelationships between the areas of concern.

Commission Objectives:

- The Commission will direct an investigation and coordinate a comprehensive review of all aspects of the World Trade Center disaster. The Commission will take a "lessons learned" type of approach in its review and analysis of the disaster.

- The Commission will utilize the expertise of nationally recognized individuals in the fields of architecture, engineering, forensic investigation, construction methods and materials, fire protection and life safety, human behavior, firefighting, search and rescue, terrorism, building/fire code development and emergency management.

- The Commission will prepare a set of detailed recommendations for the improvement of building designs, building materials, safety regulations and building codes, as well as emergency response procedures.

- The Commission could form the model for a portion of an enhanced disaster investigation protocol.

Establishment of the Commission:

Given the role of FEMA in disaster response and hazard mitigation, it is logical to have the Commission operate under the auspices of FEMA. FEMA would play the role of coordinator and provide staff and facility support (including the development of a final report).

The Commission should have a "core" of eight primary members, including a Chairman, a Vice Chairman, and designated leaders from each of the six focus areas identified below. All eight of the Commissioners would meet on a regular basis to share information, identify needs, and to direct the overall activities of the Commission.

Six Primary "Focus Areas" of Commission:

- *Building Design*
- *Building Collapse*
- *Firefighting Procedures*
- *Building Evacuation*
- *Search and Rescue Operations*
- *Building Codes and Regulations*

Examples of "Focus Area" Inquiries:

Building Design

- Identify general design concepts ("lightweight" construction, loads, etc.).
- List fire protection features in original design and improvements.
- Describe fire protection and life safety upgrades after 1993 attack.
- Establish means of egress design objectives.

Building Collapse

- *Create chronology of events leading to collapse.*
- Examination of physical evidence to identify failure mode(s) leading to collapse.
- Examination of physical evidence to assess material behavior.
- Model fire behavior (temperature, heat release rate, etc.), including contribution of jet fuel.
- Create fire and structural models to illustrate building conditions for duration of incident.

Firefighting Procedures

- Interview surviving firefighters, review radio transmissions, and analyze reports to create as complete a "picture" of firefighting response as possible.
- "Map" and analyze incident command structure.

- Establish the overall goals of incident command officers, including use of "standard" high-rise firefighting strategies.
- Enumerate tactical problems encountered by fire companies.
- Detail radio transmission problems at incident.

Building Evacuation

- Analyze building evacuation procedures, including directions given to occupants by building staff.
- Interview evacuees to collect their observations and experiences during evacuation.
- Model the evacuation including time of egress, points of constriction, crossovers delays, etc.
- Highlight the effects of improvements made after 1993 attack.

Search and Rescue Operations

- Detail coordinated effort between FDNY and USAR teams.
- Establish impact of "self-responders" on rescue operations.
- Analyze performance of "tools and technologies" used in search efforts (robots, "listening devices," cutting equipment, etc.).
- Detail efforts of maintaining "scene safety."

Building Codes and Regulations

- Establish national standards/codes in effect at time of construction.
- Identify the deficiencies of ASTM E-119 (a national test standard that establishes structural fire resistance of various fire resistive materials) when compared with the fire conditions experienced during the incident.
- Review the high-rise requirements found in current national building codes in context of this incident.
- Correlate accepted terrorism design strategies with this incident and develop design criteria for inclusion in building codes.

The Final Report of the Commission:

Upon completion of the investigation and research efforts, a final report should be issued. The report will tell the story of the disaster, highlight the lessons learned, identify additional research needs, and provide a set of specific recommendations. General examples of recommendations could include the following:

- Identification of building/fire code provisions that need to be added/updated/deleted.
- Procedural changes for fire service response to high-rise and terrorist incidents
- Changes in evacuation procedures and egress capacity criteria

GLENN P. CORBETT

(b)(6)

Home: (b)(6)
Work:

SUMMARY: Extensive experience in different facets of fire protection including the fields of firefighting and fire prevention. In-depth knowledge of the development and trends of the American fire protection profession.

EXPERIENCE:

January 1995 to Present — **John Jay College of Criminal Justice,** New York, New York
Assistant Professor of Fire Science
Coordinator, Undergraduate Fire Science Programs
Director, Graduate Protection Management Program (Jan. 1995 – June 1997)

- Prepare and teach fire science courses at the undergraduate and graduate level
- Manage and coordinate course offerings in undergraduate fire science and fire and emergency services programs, including internet offerings
- Provide guidance to existing and prospective fire science students

Sept. 1994 to Dec. 1994 — Lecturer, Fire Science

April 1993 to April 1994 — **PennWell Publishing Company,** Saddle Brook, New Jersey
Technical Director, *Industrial Fire Safety* Magazine

- Provided and maintained technical editorial direction of an industrial fire protection and safety magazine, *Industrial Fire Safety*
- Reviewed all articles submitted for publication for accuracy and relevancy

August 1987 to April 1993 — **San Antonio Fire Department,** San Antonio, Texas
Administrator of Engineering Services

- Established Engineering Services Office, including procedures, policies, and the physical plant
- Directed and evaluated staff consisting of fire protection engineer and 3 plan reviewers
- Managed all plan reviews conducted by the department including (annually) 2000 building permits (1500 interior remodels, 500 new structures) and fire protection system plans (500 sprinkler, 350 fire alarm, and other types of systems)
- Coordinated fire prevention activities with other city departments such as Building Inspections and Planning
- Coordinated, prepared, and taught 250+ hour fire inspector training course
- Served/assisted various city committees such as a Development Task Force, Board of Appeals, and Blue Ribbon Fire Department Study
- Provided technical assistance to architects, engineers, developers, and contractors
- Assisted in the preparation of new fire code and amendments

March 1986 to August 1987 — **Austin Fire Department,** Austin, Texas
Fire Protection Engineer

- Reviewed fire protection system plans as well as water supply plans for code compliance
- Assisted uniformed personnel in the review of building permit plans
- Assisted in the preparation of code policy manual for development community
- Responded to multiple alarm fires to provide on-scene technical assistance

1985 — **A.B.C. Loss and Fire Prevention Corp.,** East Orange New Jersey
Loss Prevention Consultant

- Estimated and designed automatic sprinkler systems

- Monitored sprinkler system installations and evaluated existing systems

Concurrent
Fire Engineering Magazine, **PennWell Publishing Company**, Fair Lawn, N.J.
Consulting Editor, August 1986 - September 1990
Editorial Advisory Board Member/Columnist, October 1990 - April 1993
Technical Editor/Columnist, April 1993 - Present
Fire Department Instructors Conference Planning Committee member (1997 - present)

1978 - 1986 & 1994 - present
Waldwick Volunteer Fire Department, Waldwick, New Jersey
Volunteer Firefighter (Through Dec. 1995)
Deputy Municipal Fire Coordinator (Jan. 1996 – Aug. 1997)
Second Lieutenant (Sept. 1997 – Dec. 1997)
First Lieutenant (Jan. 1998- Dec. 1998)
Second Captain (Jan. 1999 – Dec. 2001)
First Captain (Jan. 2002 – Present)

1979 - 1986
Paterson Fire Department, Paterson, New Jersey
Auxiliary Firefighter

EDUCATION: Worcester Polytechnic Institute, Worcester Massachusetts
(b)(6) M. Eng., Fire Protection Engineering
Thesis: "Water Supply Evaluation for Firefighting"

John Jay College of Criminal Justice, New York, New York
(b)(6) B.A., Fire Service Administration, Cum Laude
Dean's List, (b)(6)

MEMBER:
Bergen County Fire Chief's Association
International Association of Fire Chiefs
International Society of Fire Service Instructors
National Fire Protection Association
New Jersey Society of Fire Service Instructors (currently serving as President)
Society of Fire Protection Engineers

COMMITTEE: "America Burning: Re-commissioned" Panel, appointed By Federal Emergency Management Agency (FEMA) Director James Lee Witt in August 1999

Fire Code Advisory Council, State of New Jersey

CERTIFICATION/LICENSE:
State of Texas:
Professional Engineer's License, (b)(6)
Inactive certification as Class "A" Fire Inspector and Basic Fire Instructor

State of New Jersey:
Firefighter I, (b)(6)
Fire Official

Statement of

Dr. Arden L. Bement, Jr.

Director
National Institute of Standards and Technology
United States Department of Commerce

Before the

Committee on Science
House of Representatives
United States Congress

"Learning from 9/11: Understanding the Collapse of the World Trade Center"

March 6, 2002

Good afternoon Chairman Boehlert, Ranking Member Hall, and Members of the Committee. I want to thank you for this opportunity to testify on the investigation into the collapse of the World Trade Center Towers. The tragedy that the United States experienced on September 11, 2001, was unprecedented when compared with any prior accident, natural disaster, or terrorist/war attack. The collapse of the twin World Trade Center towers was the worst building disaster in human history. Engineers, emergency responders, and the nation did not anticipate, and were largely unprepared for, such a catastrophe. Among other national needs, these events highlight the following technical priorities:

- To establish the probable technical causes of the collapses and derive the lessons to be learned;
- To develop and disseminate immediate guidance and tools to assess and reduce future vulnerabilities; and
- To produce the technical basis upon which cost-effective changes to national practices and standards can be developed.

Shortly after the attacks on the World Trade Center, NIST's building and fire researchers began assisting federal and local agencies in many ways to investigate the spread of fire through the buildings and their subsequent collapse. Our researchers used previously developed models along with preliminary information from videos of the attack and other sources to simulate the spread of fire and smoke in the buildings. At the request of the Federal Emergency Management Agency (FEMA), NIST conducted a comparison and analysis of the current building and fire codes of New York City with national codes, and we contributed to the Army Corps of Engineers' study of the structural and fire damage to the Pentagon. In addition, NIST experts participated in the initial assessment of the collapse conducted by the American Society of Civil Engineers (ASCE) Coalition that comprised a Building Performance Assessment Team (BPAT) funded by FEMA. The ASCE Coalition Team also included professional members of the Society of Fire Protection Engineers (SFPE), the National Fire Protection Association (NFPA), the American Institute of Steel Construction (AISC), and the Structural Engineers Association of New York (SEAoNY). NIST is lending its expertise in structural disasters to ASCE and the Structural Engineers Association of New York (SEAoNY) to store WTC steel at its Gaithersburg, MD, headquarters for further scientific study.

However, more needs to be done. A growing number of technical experts, industry leaders, and families of victims are pressing for a broad-based Federal investigation to study the building construction, the integrity of the materials used, and all the technical conditions that combined to cause the building disaster at the World Trade Center ***[Witness would like to submit for the record, letters received supporting a federal investigation]***. NIST has begun working informally with a coalition of organizations – representing key industry, standards, codes, and professional groups – in an effort to launch a comprehensive public-private response program that includes such an investigation. NIST is also working very closely with FEMA, since an in-depth technical investigation would go well beyond the scope of the building performance assessments conducted by FEMA following major disasters. The implementation of the results of such an investigation would be critical to restore public confidence in the safety of tall buildings nationwide, enhance the safety of fire and emergency responders, and better protect people and property in the future. To cite one example, the February 4th issue of "Crain's New York Business" reports that an increasing number of tenants are leaving the Empire State Building, which is again the tallest building in New York City, because of fears of another terrorist attack. Anecdotal evidence also suggests that building vacancy rates have doubled in Manhattan, despite the 15 million square feet of space that was lost on September 11th.

NIST has received policy approval from the Secretary of Commerce to initiate and, after consultation with local officials, to conduct an independent and comprehensive "National Building and Fire Safety Investigation of the World Trade Center Disaster" under NIST's existing legislative authorities (15 U.S.C. 281a). Among Federal laboratories, NIST is uniquely qualified to conduct such a comprehensive investigation. The Building and Fire Research Laboratory is the foremost fire research laboratory in the United States, and through the National Earthquake Hazards Reduction Program (NEHRP) NIST is the principal agency for research and development to improve building codes and standards. NIST has extensive experience and expertise in conducting disaster investigations following structural/construction failures, fires, earthquakes, hurricanes, and tornadoes. These have included the well-known investigations into the 1981 collapse of a walkway in the Kansas City Hyatt Regency Hotel, the 1986 Dupont Plaza Hotel fire in San Juan Puerto Rico, the 1994 Northridge earthquake collapses, and the 1995 Kobe, Japan earthquake building collapses, to name just a few. In compliance with statutory requirements NIST has already consulted with local authorities in New York, including the Port Authority of NY & NJ, the Mayor's Office of Emergency Management, the New York City Department of Design and Construction, and the Fire Department of New York. These organizations have expressed support for NIST and agreed to cooperate in it's investigation.

The proposed investigation would involve world-class experts from industry, academia, and other laboratories to complement NIST's excellent in-house technical expertise. Supplementing the outstanding work done through the building performance assessment team initially assembled through FEMA, NIST would delve deeper into the factors related to the collapse. NIST would use the results of the soon to be released ASCE Coalition team's study as a valuable source of input into the investigation. The objectives of the NIST investigation would be to determine technically:

- Why and how the World Trade Center buildings collapsed following the impacts of the planes;
- Why the injuries were so high or low depending on location, including all technical aspects of fire protection, response, evacuation, and occupant behavior and emergency response;
- Whether or not state-of-the-art procedures and practices were used in the design, construction, operation, and maintenance of the World Trade Center Buildings; and
- Whether there are new technologies or procedures that should be employed in the future to reduce the potential risks of such a collapse.

The NIST investigation would focus primarily on World Trade Center Buildings 1 and 2 (the Twin Towers) for several reasons. First, the collapse of the Towers was the triggering event that caused much of the collateral damage to the adjacent properties. Second, many structural and fire protection design features and construction details found in the Towers are widely used in the building construction industry. Third, to study procedures and practices used to assess the safety of innovative structural systems and building designs not covered by existing building codes or prior in-use experience as was the case of the twin towers, and whether such practices are adequate to detect and remedy inherent vulnerabilities. Fourth, to study procedures and practices used to provide adequate structural reserve capacity to resist abnormal loads (e.g. blast, explosion, impact due to aircraft or flying debris from tornadoes, accidental fires, and faulty design and construction), especially those that can be anticipated prior to construction (e.g. impact of a Boeing 707). Fifth, the Twin Towers would provide the opportunity to study the effectiveness of fire protection and firefighting technologies and practices for tall buildings, including emergency mobility and egress, and communication systems. And lastly, the analytical tools used in these investigations would be experimentally verified and widely applicable to other building types. Besides the Towers, the investigation would possibly consider examining WTC Building 7, which collapsed later in the day.

NIST would use an open and inclusive process in formulating its work plan for the investigation. This would involve the participation of technical experts from industry, academia, and other laboratories as well as liaison with federal, state, and local authorities. NIST would expect to complete its investigation and issue a final report in 24 months.

The results of the proposed investigation would be extremely valuable in establishing the probable technical causes of the disaster and deriving the lessons to be learned, but it would be meaningless unless we take the knowledge gained and put it to practical use. That is why NIST, in partnership with FEMA and a number of private sector organizations, has developed a broader response program. This broader program would address critically and urgently needed improvements to national building and fire standards, codes, and practices that have begun to be recognized in recent years. The events of September 11th have brought even more focus and priority to this already important issue.

The goal of this broader program would be to produce cost-effective retrofit and design measures and operational guidance for building owners and emergency responders. The program would develop and disseminate guidance and tools to assess, and produce the technical basis and recommendations for cost-effective changes to reduce vulnerabilities.

Over the course of the proposed investigation and broader program there would be a number of short-term and interim work products that would provide guidance, tools, and technical assistance to better prepare facility owners, contractors, designers, and emergency personnel for future disasters. Some of these products, based on prior NIST work, would be disseminated broadly as soon as possible. Others that need further refinement would be disseminated within a year, and the rest after the completion of the investigation. I would like to note that the President's FY 2003 budget request for NIST contains a $2 million funding increase, which will go towards this effort and related research.

Let me now give you three examples of work that would be accomplished through this broader program.

First, fire played a critical and visible role in the collapse of the WTC buildings and contributed to damage to the Pentagon buildings. Current building design practice does not consider fire as a design condition. Instead, structural fire endurance ratings are prescribed in building codes using standard tests on individual components. The current testing standards are based on work carried out at NIST in the 1920s. They do not represent real fire hazards in modern buildings. They also do not consider the fire performance of structural connections or of the structural system as a whole, or the multiple performance demands on fire proofing materials. NIST now has the capability to simulate building fires on the computer to explain critical events and outcomes to an extent previously not possible. The proposed work would expand on this core competence in computational methods, and adapt measurement techniques and test methods to support the prediction of performance of building materials, products, structural elements, and systems up to the point of the collapse of a tall building due to fire. In short, NIST would provide the technical basis and guidance for fire safety design and retrofit of structures, the predictive tools and test methods for fire resistance determination, and the performance criteria for fireproofing materials. In addition, NIST proposes to develop guidance and retrofit technologies to enhance building egress in emergencies, practical tools and guidance to enhance the safety and effectiveness of fire and emergency responders, and improved models of occupant behavior and response to enhance evacuation and communication in emergencies.

Second, progressive collapse – which refers to the spread of failure by a chain reaction that is disproportionate to the triggering event – was also responsible for the extraordinary number of deaths in the 1995 bombing of the federal building in Oklahoma City. Yet, the United States has not developed standards, codes, and practices to assess and reduce this vulnerability. Adding to the problem for modern structures is their smaller margin of safety – and the reserve capacity to accommodate abnormal loads – due to increased efficiency in the use of building materials and refinements in analysis techniques. The work carried out at NIST in the early 1970s continues to provide the basis for the extremely limited guidance that is available in current United States standards. NIST would develop cost-effective solutions to reduce building vulnerability to progressive collapse using a multi-hazard approach that exploits synergies in resisting extreme loads from blast, impact, earthquakes, and fires.

Third, vulnerability reduction of commercial and institutional buildings and facilities. The overwhelming majority of buildings in public use today are vulnerable to terrorist attack on a number of fronts. Most lack state of the art sensing and information management systems. Few have electronic representations of the building documents or models, and standards do not exist for such representations. Most are not protected against chemical, biological, and radiological (CBR) threats. While efforts are underway to protect military buildings through Department of Defense's "immune buildings" program, there are no standards and practices for civilian buildings. NIST proposes to work with the DoD to develop guidelines and advanced technologies to reduce the vulnerability of such buildings to CBR attacks. NIST also proposes to work with industry to develop standards for building information models and information exchange, and practicable tools for helping building owners make reasoned economic choices in reducing the vulnerabilities of their buildings.

The final program element supports a construction-industry-led roadmapping effort to reflect changed priorities for development and deployment of safety and security standards, technology, and practices. It would also support the delivery and dissemination of practical guidance, tools, and technical assistance to better prepare facility owners, contractors, designers, and emergency personnel to respond to future disasters and to speed economic recovery within the industry following disasters. The effort would complement and support parallel efforts of technical organizations to improve standards, codes, and practices.

In conclusion, I believe it is imperative for the U.S. to learn from the worst-ever building disasters in human history and take aggressive remedial action to minimize future losses. As the events of September 11 demonstrated, the very stability of U.S. commerce and our economy depends upon major buildings and critical facilities that provide a key part of our Nation's physical infrastructure. In the wake of September 11th, the private sector's willingness to take necessary corrective action to strengthen building codes and standards is extraordinarily strong. So with the envisioned Federal technical leadership and partners from the private sector, changes can be made to minimize the likelihood and consequences of future disasters. Thank you, Mr. Chairman. I would be happy to take questions from the Committee.

Purdue University News Service

Arden L. Bement, Jr., Director

Arden L. Bement, Jr., was sworn in as the 12th director of NIST on Dec. 7, 2001. Bement oversees an agency with an annual budget of about $812 million and an onsite research and administrative staff of about 3,000, complemented by a NIST-sponsored network of 2,000 locally managed manufacturing and business specialists serving smaller manufacturers across the United States. Prior to his appointment as NIST director, Bement served as the David A. Ross Distinguished Professor of Nuclear Engineering and head of the School of Nuclear Engineering at Purdue University. He has held appointments at Purdue University in the schools of Nuclear Engineering, Materials Engineering, and Electrical and Computer Engineering, as well as a courtesy appointment in the Krannert School of Management. He was director of the Midwest Superconductivity Consortium and the Consortium for the Intelligent Management of the Electrical Power Grid.

Bement came to his position as NIST director well versed in the workings of the agency, having previously served as head of the Visiting Committee on Advanced Technology, the agency's primary private-sector policy adviser; as head of the advisory committee for NIST's Advanced Technology Program; and on the Board of Overseers for the Malcolm Baldrige National Quality Award.

Bement joined the Purdue faculty in 1992 after a 39-year career in industry, government, and academia. These positions included: vice president of technical resources and of science and technology for TRW Inc. (1980-1992); deputy under secretary of defense for research and engineering (1979-1980); director, Office of Materials Science, DARPA (1976-1979); professor of nuclear materials, MIT (1970-1976); manager, Fuels and Materials Department and the Metallurgy Research Department, Battelle Northwest Laboratories (1965-1970); and senior research associate, General Electric Co. (1954-1965).

Along with his NIST advisory roles, Bement served as a member of the U.S. National Science Board, the governing board for the National Science Foundation, from 1989 to 1995. He also chaired the Commission for Engineering and Technical Studies and the National Materials Board of the National Research Council; was a member of the Space Station Utilization Advisory Subcommittee and the Commercialization and Technology Advisory Committee for NASA; and consulted for the Department of Energy's Argonne National Laboratory and Idaho Nuclear Energy and Environmental Laboratory.

He has been a director of Keithley Instruments Inc. and the Lord Corp. and was a member of the Science and Technology Advisory Committee for the Howmet Corp. (a division of ALCOA).

Bement holds an engineer of metallurgy degree from the Colorado School of Mines, a master's degree in metallurgical engineering from the University of Idaho, a doctorate degree in metallurgical engineering from the University of Michigan, and a honorary doctorate degree in engineering from Cleveland State University. He is a member of the U.S. National Academy of Engineering.

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Testimony of Dr. W. Gene Corley

Senior Vice President
CTL Engineering
Chicago, IL

On behalf of the

American Society of Civil Engineers

Before the
Subcommittee on Environment, Technology and Standards
&
Subcommittee on Research

Committee on Science
U.S. House of Representatives

March 6, 2002

The tragic events of September 11 have served as a grim reminder that there is no limit to the destructive forces than man can use to damage or destroy our nation's infrastructure. The civil engineering profession, as stewards for our nation's infrastructure, feels obligated to make certain the critical public works our communities and nation depend on are protected. Through the American Society of Civil Engineers (ASCE), the profession has taken a leading role in addressing infrastructure vulnerability and is developing both short- and long-term strategies to mitigate the impact of future disasters on our critical civil infrastructure.

Founded in 1852, ASCE represents more than 125,000 civil engineers worldwide and is the country's oldest national engineering society. ASCE members represent the profession most responsible for the nation's built environment. Our members work in consulting, contracting, industry, government and academia. In addition to developing guideline documents, state-of-the-art reports, and a multitude of different journals, ASCE, an American National Standards Institute (ANSI) approved standards developer, establishes standards of practice such as the document known as ASCE 7 which provides minimum design loads for buildings and other structures. ASCE 7 is used internationally and is referenced in all of our nation's major model building codes.

In response to the events of September 11th, ASCE is implementing a multifaceted response plan, significant elements of which are outlined here. Following this abbreviated outline of our initiative is a more detailed discussion of ASCE's efforts related to the World Trade Center.

ASCE's Critical Infrastructure Response Initiative

On October 9, 2001, the ASCE Board of Direction voted to expend money from reserves on a Critical Infrastructure Response Initiative (CIRI). The objective of CIRI is to establish strategies and guidelines for:

1. Assessing U.S. infrastructure vulnerability.
2. Using the results of vulnerability assessments to prioritize infrastructure renovation.
3. Identifying research and development needs for new approaches to protecting critical infrastructure.
4. Developing retrofit designs to mitigate damage from disasters.
5. Developing new approaches to design and construction.
6. Improving disaster preparedness and response.

To accomplish the CIRI objectives, ASCE has undertaken the following activities:

1. Review and evaluate existing and pending legislation regarding infrastructure, and provide appropriate input.
2. Identify existing and pending infrastructure initiatives by other professional and technical associations to identify opportunities for partnering, and to avoid duplication of efforts. For example, EPA has several water supply initiatives underway with AMWA. These initiatives, however, are currently focused on

operations and management, and ways will be sought to provide input regarding design and construction issues.

3. Identify existing and pending infrastructure initiatives by federal agencies to identify opportunities for partnering.
4. Create a liaison or partnership with the Office of Homeland Security regarding the assessment of infrastructure vulnerability and the design and construction of mitigation measures.

In each of these areas, ASCE stands ready to assist other organizations, both public and private, to reduce the vulnerability of our nation's infrastructure.

ASCE's Efforts Related to the World Trade Center

Building Performance Study Teams

On the afternoon of September 11, 2001, the Structural Engineering Institute of ASCE (SEI/ASCE) began assembling two teams of experts to study the performance of the buildings at the World Trade Center Complex and the Pentagon. The goal of the studies is to increase our knowledge and understanding of how buildings subject to extreme forces, such as those caused by the crash and resulting fires, perform under these unusual circumstances.

The scope of the WTC study team is quite broad. Although much of the nation's attention has been riveted to the collapse of the twin 110-story towers, the WTC team is also examining several of the buildings in the surrounding area to determine what lessons might be learned from the performance of those structures as a result of their being impacted by falling debris and ensuing fires. Of particular interest to the engineering community is the performance of WTC 7 and the Banker's Trust Building.

Studies of this type have been performed by ASCE following other disasters under the authority of ASCE's Disaster Response Procedure, which provides the internal mechanism to organize and fund these studies. This was the fifth time in 2001 that the procedure was used to create study teams. Earlier teams, whose members were experts in earthquakes and lifeline engineering, were dispatched to study and document the damage from the earthquakes in El Salvador, India, Seattle, and Peru. In 1995, ASCE, in partnership with FEMA, organized a team to examine the Murrah Federal Office Building in Oklahoma City and surrounding area after the bombing.

Team Members and Partnering Organizations

The teams assembled by SEI/ASCE are comprised of leading experts in the fields of structural analysis and design, fire engineering, blast effects, and building materials. On October 1st, the WTC study became a joint effort between ASCE and the Federal Emergency Management Agency (FEMA), a partnership, which continues to this day.

The partnership with FEMA has proven to be extremely beneficial to the overall success and progress of the WTCteam. In addition to providing funds, FEMA has provided logistical assistance, organizational and operational guidance, assistance in obtaining and organizing the needed data, and will provide the resources to publish the report. Utilizing the FEMA standard operation procedure for post-disaster engineering studies, managed through a contract with the architecture and engineering firm, Greenhorne & O'Mara, Inc., FEMA helped organize and coordinate the on-site operation of the BPS Team as they performed their initial data-collection efforts in New York City.

The WTC team is headed by W. Gene Corley, Ph.D., P.E., a preeminent expert on building collapse investigations and building codes. A full list of team members and an indication of their areas of expertise is attached. Dr. Corley, whose biography is attached, was the team leader and principal author of the ASCE/FEMA Murrah Federal Office Building Study Report in 1995.

The Pentagon team is headed by Paul Mlakar, Ph.D., P.E., of the U.S. Army Corp of Engineers Waterways Experiment Station in Vicksburg, Mississippi. Dr. Mlakar is a preeminent expert in blast engineering and was also a member of the ASCE/FEMA team, which examined the Murrah Federal Office Building.

In addition to assembling the teams of experts, SEI/ASCE has also organized a coalition of professional organizations to participate and support the work. These partnering organizations include: the Society of Fire Protection Engineers (SFPE), which provided recommendations of team members; the National Fire Protection Association (NFPA), which provided counsel on the fire engineering aspects of the study; and the Structural Engineers Association of New York (SEAoNY), which provided on-going assistance in the examination of the debris. It should be noted that SEAoNY, on its own initiative, was instrumental in providing assistance to the rescue and recovery operations immediately after the attacks. Additional members of the coalition are the American Institute of Steel Construction, Inc. (AISC), the American Concrete Institute (ACI), the Council of American Structural Engineers (CASE), the Council on Tall Buildings and Urban Habitat (CTBUH), the International Code Council (ICC), the Masonry Society (TMS) and the National Council of Structural Engineering Associations (NCSEA).

To increase our knowledge and understanding of the performance of the structures, the study is focusing on the response of the buildings, including fire behavior, structural design, fireproofing characteristics, and damage resulting from the aircraft impacts. As a result of this study, the structural and fire protection engineers comprising the team hope to provide an accurate description of the events and a preliminary assessment of the behavior of the affected buildings.

Data Collection

Simultaneous with the efforts to assemble the team and organize the supporting coalition, work began to collect data and information pertinent to the study. A significant part of this data collection phase was holding a meeting of the team in New York City to examine the wreckage and the surrounding buildings impacted by the collapse. On September 29th, the City of New York granted the team access to the World Trade Center site and from October 7th to the 12th, the entire team was on site. The team was provided with unrestricted access to all areas of the site except for areas where their presence might have impeded the on-going rescue and recovery efforts and areas which were determined to be extremely hazardous. To aid the team in this intense 6-day effort, FEMA made its Regional Operation Center (less that 8 blocks form the WTC site) available for use by the team on a 24-7 basis.

During this time period, team members also examined structural debris at the Fresh Kills Landfill on Staten Island and at the two recycling yards in New Jersey. Samples of structural steel were obtained and have since been subjected to laboratory analyses. Under the guidance of selected team members, numerous professional engineers who are members of SEAoNY are continuing this work on the team's behalf and have been visiting recycling yards and landfills regularly since the beginning of November. Additional samples of the structural steel have been obtained and are presently being stored at the National Institute of Standards and Technology in Gaithersburg, Maryland for use in future studies.

Unlike other structural collapses, there is an unprecedented volume of photographic and video evidence available for the team to review, including more than 120 hours of network and private video footage. Individual team members have viewed every foot of this videotape and provided information on the available data to the team at large.

Beyond the information and data pertaining to the events on September 11th, there is also a need to establish, as accurately as possible, the physical attributes of the towers and surrounding buildings prior to the impact of the airplanes. Doing this is a monumental task. The construction of the towers was documented by literally thousands of engineering drawings. In addition, there were numerous changes to the towers over their life. This effort is also being conducted for WTC 7, which is of considerable interest to the team. These data, together with the data previously described will be used to construct detailed computer models of the structures.

Impediments Encountered by the Building Performance Study Teams

In the 10 years in which ASCE has been conducting studies of disasters we have learned that our teams will always encounter impediments. It is therefore not surprising that the study team has encountered some difficulties in their data collection activities. However, we have also learned that with time and persistence these difficulties are either overcome or an alternate approach is found to enable the team to satisfactorily complete their study as described below.

When studying damaged structures it is important to understand the physical nature of the original structure as soon as possible. Commonly this is accomplished by obtaining and studying the engineering plans of the structures. Because the team did not have the engineering plans of the affected structures during the site visit in early

October, arrangements were made to have several of the principal designers make presentations to the team. These briefings enabled the team to conduct their site visit more efficiently and to better understand the structure of the affected buildings. The delay in the receipt of the plans hindered the team's ability to confirm their understanding of the buildings. Through the efforts of FEMA and others, the team received the engineering plans for the WTC Towers on January 8, 2002, and work is proceeding.

As noted previously, there is an enormous volume of video and photographic documentation of the events of September 11th. This type of evidence can often yield significant insights into the failure mechanisms but it is imperative that the highest quality video footage be used. The team did experience some difficulty in obtaining video footage from the various television networks.

Obtaining access to the site of a disaster is always difficult and clearly the search and rescue efforts and any criminal investigation must take first priority. However, in all studies of this nature, gaining access to the site as soon as possible is important in order to observe and document the debris and site conditions. For the future, it may be useful to consider some protocol or process whereby selected individuals from the BPST would be allowed on site in the initial days after a catastrophic event to gather critical data.

There has been some concern expressed by others that the work of the team has been hampered because debris was removed from the site and has subsequently been processed for recycling. This is not the case. The team has had full access to the scrap yards and to the site and has been able to obtain numerous samples. At this point there is no indication that having access to each piece of steel from the World Trade Center would make a significant difference to understanding the performance of the structures.

Resources are always an issue with building performance studies, particularly for one whose magnitude and scale is unprecedented. The total amount of resources being dedicated to support the team's activities is approximately $1 million, which has allowed the team to do the initial reconnaissance of the site and the building materials, begin the process of hypothesis setting, and conduct some limited testing. This raises the question of what amount of money would be sufficient. It is our opinion that $40 million would be a sufficient amount to fully fund a comprehensive study of an event of this magnitude and complexity.

A Protocol for Future Building Performance Study Teams

The Building Performance Assessment Team program in place within the Federal Emergency Management Agency (FEMA) has a long and distinguished history of providing excellent information to the engineering profession. The BPAT program has a detailed protocol in place which has been continually refined and improved upon throughout its use.

Similarly, ASCE's Disaster Response Procedure has been successfully used by ASCE to conduct important studies of significant disasters. ASCE's procedure also has been refined and improved upon through its history.

The history of both of these programs however has been predominantly with natural disasters such as hurricanes, earthquakes or floods. While it is certainly our sincere hope that the anti-terrorist efforts of our government will prove successful, it may be useful to review the existing protocols from the perspective of their application to major, unprecedented events such as the terrorist attack on the World Trade Center. This could address some of the impediments that were discussed above.

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A Case Study for Improved Building Practices?

As many in the United States and the world examine the future of tall buildings it is important to look at how well these buildings performed under extreme circumstances. It must be remembered that large commercial aircraft hit the World Trade Center Towers, yet both withstood the initial impact. Additionally, as has been widely reported, almost all of the individuals in the buildings below the impact zone were able to get out of the buildings to safety. Efforts such as that being conducted by the Building Performance Study teams and studies emanating from this initial study will seek to extend the performance of structures to allow occupants ample time to reach safety.

Because there is no limit to the destructive forces which terrorists can bring to bear against our built infrastructure it is impossible to design a building to withstand such an attack. The multi-faceted approach presently being pursued, that being to prevent the attack initially and pursue rational, scientifically based methods to improve structural performance, is both sound and prudent.

Future Research Needs for Civil Engineering

As has occurred throughout the world, the events of September 11th have created new challenges for the civil and structural engineering communities. Solving the problems presented by these challenges will be neither easy nor quick, and will require the collective efforts from a broad range of engineering and scientific disciplines.

While there will be a number of specific issues and recommendations in the reports being issued by the ASCE/FEMA WTC study team and the ASCE Pentagon study team later this spring, there are several high priority needs from the structural engineering community to which I would like to draw your attention:

> **Progressive Collapse:** The likelihood of a building or structure collapsing progressively is dependent upon two inter-related through separate behaviors: the event or load to which the structure is subjected and the strength or redundancy of the structure. At present, there is no rational technical basis to specify the initiating event or conversely to evaluate the effectiveness of alternative mitigation strategies, either alone or in combination. While virtually all structures contain some degree of

redundancy, we must now live, build and function in a world where the performance demands placed on our built infrastructure have been altered, thereby necessitating the development of engineering-based tools to guide our profession in the future.

Fire-Structure Interaction: While events such as those of September 11th are rare, and through the efforts of the President and Congress will be even less likely in the future, normal fires in buildings and other structures are not rare events. To continue to improve the performance of structures in a fire environment will require the development of new tools and design methods through the collaboration of the fire engineering and structural engineering communities for application to both new and existing buildings. This work should include tools by which to address fire as a structural design load, understanding the behavior of structural connections under fire conditions, and a coupling between fire dynamics and structural response.

We believe that each of these needs are crucial to advancing the health, safety, and welfare of the citizens of our nation. Each of these priorities are also highly complex and will require a substantial partnership between public agencies and private organizations to accomplish this work.

In the private sector, ASCE has begun this work through the establishment of a multi-disciplinary coalition of engineering organizations. This coalition, led by the Structural Engineering Institute of ASCE, includes the Society of Fire Protection Engineers, the National Fire Protection Association, the Structural Engineers Association of New York, and the International Code Council. Taken in combination, this coalition represents over 250,000 architects, engineers and scientists who stand ready to bring their talents and expertise to meeting the needs of our nation.

In the public sector, the National Institute of Standards and Technology's (NIST) Building and Fire Research Laboratory (BFRL), as the only federal laboratory dedicated to both building and fire research, BFRL can play a key role in assessing and addressing the vulnerability of the nation's buildings and physical infrastructure. The public-private response program that has been established with significant NIST leadership encompasses the critical needs identified above. We urge you to provide the support and resources sought by NIST so that together we can continue to provide the reliability and performance which our country expects from our physical infrastructure.

Conclusion

Thank you for the opportunity to express ASCE's views. We offer you and all of the agencies involved in the recovery efforts ASCE's full resources to manage the nation's critical infrastructure needs. We are ready to help in any way possible, and I am eager to hear from you regarding ways that ASCE's CIRI can support you as you examine our infrastructure needs in the coming months.

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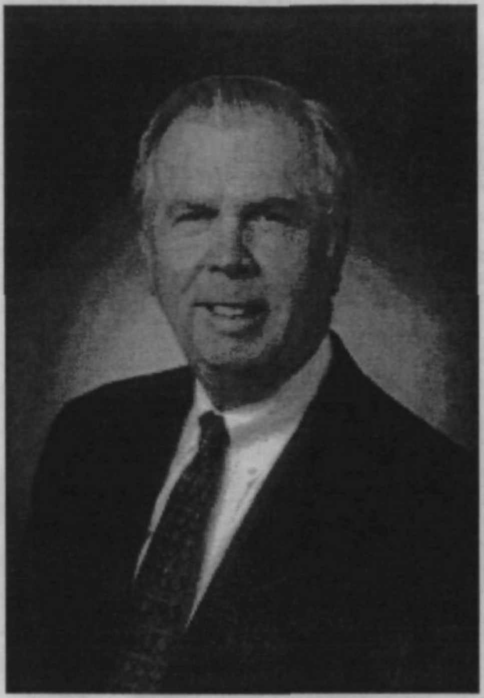

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Educational Background •
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Chartered Engineer, FI Struct E, UK

CTL Experience • Dr. Corley has served as CTL Vice President since 1987. In this position, he serves as CTL's managing agent for professional and structural engineering and leads structural evaluation projects related to industrial, transportation and parking facilities, bridges and buildings. He also is active in projects related to earthquake engineering. His wide range of experience includes evaluation of earthquake and blast damaged buildings and bridges; investigation of distress in prestressed concrete structures; repair of parking garages damaged by corrosion; evaluation and repair of high rise buildings, stadiums, silos and bridges; design and construction of repairs for prestressed and conventionally-reinforced, precast and cast-in-place concrete and structural steel facilities. In 1995, Dr. Corley was selected by ASCE to lead a Building Performance Assessment Team investigating the bombing of the Murrah Federal Building in Oklahoma City.

Prior Experience • After receiving his B.S. degree, Dr. Corley worked for the Shelby County, Illinois highway department where he designed highways and bridges. He then returned to the University of Illinois as a research assistant and National Science Foundation teaching fellow while pursuing his graduate studies.

Upon completion of his Ph.D., he served as a commissioned officer in the U.S. Army from 1961 until 1964. During this period, Dr. Corley was a research and development coordinator with the U.S. Army Corps of Engineers at Fort Belvoir, Virginia. His duties included bridge design, acceptance testing of mobile floating assault bridge equipment, design of tank launched bridges and fatigue testing of bridges fabricated from high strength steel, aircraft aluminum and titanium alloys.

In 1964, Dr. Corley began work as a development engineer with the Portland Cement Association. While serving in successively more responsible positions, he was directly involved in the development of improved design procedures for structural concrete, concrete pavement, railroads and structures subjected to fire loads. In addition, he served on an earthquake damage investigation team, carried out investigations of damaged or deteriorated structures and developed repair procedures for numerous buildings and bridges.

Publications and Professional Activities •
W. Gene Corley has authored more than 150 technical papers and books. He frequently lectures to technical and non-technical groups on the subjects of prevention of failures, effects of earthquakes and design and repair of structures. He regularly presents

training courses on reinforced concrete design and teaches the seismic design portion of a refresher course to candidates for the Illinois Structural Engineering License examination.

Dr. Corley chaired ACI Committee 318 for six years as the committee developed the 1995 Building Code Requirements for Structural Concrete. He also serves on several other national and international committees that prepare recommendations for structural design and for design of earthquake resistant buildings and bridges. His professional activities resulted in his receiving 11 national awards including the Best Structural Publication Award from NCSEA, Outstanding Paper from the ASCE Journal of Performance of Constructed Facilities, the Wason Award for research from ACI, the T.Y. Lin Award from ASCE and the Martin Korn Award for PCI. He also has received several regional awards, including the UIUC Civil Engineering Alumni Association's Distinguished Alumnus Award, the SEAOI Service Award, Illinois ASCE Structural Division's Lifetime Achievement Award, the Henry Crown Award, and the SEAOI John Parmer Award.

Dr. Corley serves or has served in leadership roles for numerous professional organizations, both national and international, including the following:

American Society of Civil Engineers (Fellow)
National Society of Professional Engineers (Member)
National Council of Structural Engineers Associations (Founding Member, Board of Direction, Former President)
American Concrete Institute (Fellow) Former Chairman, Committee on Standard Building Code
American Railway Engineering Association (Member)
Building Seismic Safety Council (Former Vice-Chairman and Founding Member, Board of Direction)
Chicago Committee on High Rise Buildings (Member and Former Chairman)
Earthquake Engineering Research Institute (Member and Former President, Great Lakes Chapter)
Institution of Structural Engineers, UK (Fellow)
International Association for Bridge and Structural Engineering (Member)
National Academy of Engineering (Member)
National Association of Railroad Safety Consultants and Investigators (Member)
NACE International (Member)
Prestressed Concrete Institute (Member)
RILEM (Member)
Post Tensioning Institute (Member)
Transportation Research Board (Member)
Structural Engineers Association of Illinois (Member, Former President)
Governor's Earthquake Preparedness Task Force (Illinois)

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

The Investigation of the World Trade Center Collapse: Findings, Recommendations and Next Steps

Wednesday, May 1, 2002

Noon – 3:00 PM
2318 Rayburn House Office Building

Witness List

Mr. Robert Shea
Acting Administrator,
Federal Insurance and Mitigation Administration

Dr. W. Gene Corley
American Society of Civil Engineers,
Chair of Building Performance Assessment Team reviewing the WTC disaster

Dr. Arden Bement
Director,
National Institute of Standards and Technology

Professor Glenn Corbett
Assistant Professor of Fire Sciences,
John Jay College, New York City

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COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

HEARING CHARTER
The Investigation of the World Trade Center Collapse:
Findings, Recommendations and Next Steps
Wednesday, May 1, 2002
Noon to 3:00 pm
2318 Rayburn House Office Building

1. Purpose

On Wednesday, May 1, at noon the House Committee on Science will hold a hearing on the key findings and recommendations of the Federal Emergency Management Agency's (FEMA) investigation into the collapse of the World Trade Center (WTC). The hearing will also review the plans of the National Institute of Standards and Technology (NIST) to conduct a more extensive follow-up investigation and to establish a comprehensive research and development plan to improve standards, practices and codes for buildings and fire. In addition, the witnesses will be asked to comment on a bill to give NIST additional investigative powers.

The hearing will address the following overarching questions:

1. What are the findings and recommendations of the report of FEMA's building performance assessment team (BPAT) regarding the collapse of the World Trade Center?

2. What are NIST's plans to follow up on the recommendations of the BPAT report?

3. How should NIST be involved in investigating catastrophic building failures in the future?

4. To what extent does NIST require new authorities, such as the ability to issue subpoenas, in order to conduct investigations of building failures?

2. Issues

Since the March 6, 2002 Science Committee hearing on the collapse of the World Trade Center, FEMA has readied its report of the Trade Center disaster for release, NIST has prepared initial plans for taking the reins from FEMA to conduct its own, more extensive investigation, and the Administration has requested supplemental funding of $16 million to pay for NIST's investigation. At the same time, a number of new issues have arisen:

- **It is unclear how NIST's $16 million follow-up investigation will differ from that of the BPAT's.** While NIST has made clear the goals for its proposed follow-up investigation to collect more data on the World Trade Center disaster and has outlined the general issues it plans to probe, many aspects of the investigation remain undefined. For example, it is still unclear how much data remains to be collected or what kind of data is needed to determine whether changes in building codes are necessary.

- **It is uncertain whether NIST will receive the funding necessary to pay for its planned investigation.** The Administration's request of $16 million for further investigation of the World Trade Center disaster was made on behalf of FEMA rather than NIST. While FEMA has stated that NIST is in charge of the follow up investigation and is willing to transfer this funding to NIST, it is unclear whether it has the authority to do so. FEMA has promised to have a determination from its Office of General Counsel at the time of the hearing as to whether additional authority from Congress would be required to transfer the funds to NIST.

- **It is unclear whether the second phase of NIST's follow-up plans – a 3-year research effort to determine whether and how changes in building codes should be made – will receive the commitment for funding it requires.** In addition to conducting a $16 million follow-up investigation to collect more data regarding the Trade Center disaster, NIST also proposes to conduct longer-term research on issues identified by the BPAT report. For example, NIST plans to develop computer models of the collapse and conduct experiments to better understand the effect of fire on steel connections in buildings. So far, the Administration has requested $2 million in the FY03 budget for this type of research and NIST has committed an additional $2 million next year from amounts that otherwise would go to its building and fire laboratory, the principal lab that will do the research in any case. NIST estimates, however, that the total cost of the program will be approximately $40 million over the next three years. While NIST has said that some funds may be contributed by private sources, it is unclear if any such commitments have been made. If adequate funding for NIST's research efforts are not secured it is unclear how NIST will use the information it collects in its investigation to improve standards, practices and codes for buildings and fire.

- **It is unclear what role NIST will play in investigating future building failures.** FEMA received heavy criticism at the last Science Committee hearing for shortcomings in the way in which it conducted the investigation of the collapse of the World Trade Center. Following the hearing, FEMA entered into a memorandum of understanding (MOU) with NIST to enlist NIST's support in future investigations. The details of that MOU have not yet been worked out, and it is unclear what kinds of building collapses, if any, will lead FEMA to ask for NIST's assistance in the future.

- **NIST may require additional authorities to carry out an effective building investigation.** FEMA's investigation into the World Trade Center collapse was inhibited at several turns by an inability to access the disaster site quickly, preserve evidence, and obtain necessary documentary evidence, such as blueprints, in a timely way. Several observers, including the families of the Trade Center victims, have called for World Trade Center investigators to be granted authorities akin to those of the National Transportation Safety Board (NTSB), which is authorized by statute to enter the site of airplane crashes, preserve evidence, and issue subpoenas to witnesses or for documents to facilitate its investigation.

3. Background

On September 11, 2001, terrorists crashed two fuel-laden commercial Boeing 767 airplanes into the north and south towers of the World Trade Center complex in New York City. Although each building withstood the initial impact, both suffered complete collapse within two hours. While more than 25,000 people were successfully evacuated from the towers, nearly 3,000 building occupants and emergency responders died when the buildings fell.

FEMA responded to this disaster by deploying a building performance assessment team (BPAT)—a group of experts in engineering, design, construction, and building codes—to conduct a formal analysis of the causes of the collapse of the buildings and determine what can be learned from the disaster to save lives in the future. Concerns regarding the timing of the BPAT deployment, their access to the site and building records, premature disposal of evidence, and FEMA's lack of regular communication with the public were the subject of a previous Science Committee hearing, and are explained in detail in Appendix 1 (the March 6 hearing charter).

FEMA and the American Society of Civil Engineers (ASCE), the organization heading up the WTC BPAT, will announce the results and recommendations of the BPAT report at the hearing. Preliminary drafts of the report reveal that despite the massive impacts that punctured the building's exterior frame of support, the buildings were able to successfully redistribute the weight from higher floors and remain standing. However, the fires in the buildings, fed by jet fuel and flammable building contents, proved too intense, producing at their peak an amount of energy equivalent to the output of a typical nuclear power plant. The fires caused the steel, stripped of its fireproofing by the impact of the planes, to weaken and buckle. With water pipes for fire suppression systems severed, the fires led to the eventual progressive collapse of the buildings.

The report highlights potential reasons for why the two towers, almost identical in design, performed differently under the stresses of the disaster. It also identifies critical features that enabled so many to evacuate, and the design elements that may have played a role in the collapse and prevented people above the impacts from being able to exit the buildings. (See a March 29th article from *The New York Times*, which is attached as Appendix 2, for further discussion of the BPAT's findings and recommendations.)

The report also calls for further study of several issues that were beyond the scope of the BPAT investigation. For example, the report recommends developing methods to predict performance of building materials in fires, improving existing models of how fires spread, analyzing the WTC evacuation and proposing improvements to evacuation procedures for tall buildings, involving engineers in the processes that emergency personnel use to develop plans for hazard assessment, etc. The report also outlines specific needs for further investigation into the performance strengths and weaknesses of each building within the WTC complex.

NIST Investigation and Research Program

NIST's Building and Fire Research Laboratory (BFRL) carries out research in fire science, fire safety engineering, and structural, mechanical, and environmental engineering. It is the only federal laboratory dedicated to research on building design and fire safety.

In January, FEMA asked NIST to take over the next phase of the investigation of the collapse essentially to build upon the BPAT recommendations and conduct a more thorough investigation of the events leading to the collapse. While waiting for the BPAT report to be released, NIST has developed a two-part strategy: investigation and long-term research.

First, NIST will conduct a $16 million comprehensive and thorough two-year investigation to determine, through a technical analysis, why and how WTC 1, 2 and 7 collapsed. The investigation will cover subjects including evacuation, standards that were used in the construction and maintenance of the buildings, and whether new technologies for future buildings could reduce the risk of collapse. For example, the fire-performance of steel trusses and connectors with spray-applied fireproofing is not well understood, but may have been critical to the ultimate failure of the Trade Center. NIST will purchase floor trusses similar to those in the WTC 1 & 2, spray on fireproofing as it was done in the buildings, and subject them to fire and mechanical conditions (vibrations and impacts) like those experienced on September 11. Information from these tests not only can answer questions about the exact nature of the collapse of the buildings, but also will serve as the foundation for developing performance-based criteria for fireproofing steel, which is a part of NIST's long-term research agenda.

While the first part of the strategy specifically focuses on investigating the collapse of the World Trade Center buildings 1, 2, and 7, NIST believes that many of the "lessons learned" through a technical investigation can have broad applicability to building design. NIST is developing a public-private research plan to focus on many of the long-term research needs that the BPAT report recommended. NIST estimates that this program could cost approximately $40 million over the next three years. The Administration has already requested $2 million in the FY03 budget and NIST has committed another $2 million by shifting funding in the BFRL's base funding level to this purpose. The public-private program will address four national needs:

- To develop a better understanding the response of structures and materials to fire, and options for improving the safety of existing buildings;
- To develop a better understanding human behavior in emergency evacuations, including exploring technologies to assist mobility-impaired people, and to develop standards for the equipment that fire and emergency responders use;
- To reduce the vulnerability of buildings to chemical, biological, and radiological attacks; and
- To develop a roadmap for changes to building codes, standards and designs, and for disseminating research to industry.

Calls for New Authorities for NIST

While NIST is optimistic that the investigation combined with the research plan can ultimately lead to changes in building codes, standards and practices, as well as improvements in emergency response and evacuation procedures, some NIST officials agree with families of Trade Center victims that NIST needs new authorities in order to conduct an effective investigation. They believe that, like the National Transportation Safety Board, NIST should have the authority to issue subpoenas to obtain critical documents or persuade unwilling witnesses to provide information important to the investigation. Proponents of granting NIST subpoena power point to the fact that the BPAT team had requested but were denied several kinds of documentary evidence to assist its investigation, such as the recordings of emergency responders and 911 calls made that could help investigators determine what was happening inside the World Trade Center buildings before they collapsed on September 11.

4. Witnesses

The following witnesses will address the Committee:

Mr. Robert Shea, Acting Administrator, Federal Insurance and Mitigation Administration, Federal Emergency Management Agency

Dr. W. Gene Corley, P.E., S.E., American Society of Civil Engineers, Chair of Building Performance Assessment Team reviewing the World Trade Center disaster

Dr. Arden Bement, Director, National Institute of Standards and Technology

Professor Glenn Corbett, Assistant Professor of Fire Science at John Jay College, New York City

5. Questions

The witnesses were asked to address the following issues before the Committee:

Mr. Shea:

Instead of formally testifying before the Committee, Mr. Shea will officially release the results of the BPAT study of the World Trade Center disaster and remain on the panel to respond to questions.

Dr. Corley:

Dr. Corley was asked to describe the key findings and recommendations of the World Trade Center Building Performance Study. His focus is to be on any "lessons learned" from the collapse, any recommendations to alter building codes, standards or practices, and any recommendations to which the National Institute of Standards and Technology, in its follow-up investigation and study, should be especially attentive.

The Committee posed the following questions for Dr. Corley to address in his written testimony:

- What areas critically need further study but lie outside the scope of your report?
- What additional data collecting and modeling must be done in order to derive "lesson learned" from this disaster and who should do this work?
- What barriers stand in the way of having the recommendations of the BPAT adopted in the building codes community and how can these barriers be overcome?
- What work, if any, does ASCE plan to conduct, as follow-up to this study, to develop any changes to building practices, standards and codes?

Dr. Bement:

Dr. Bement was asked to describe the $16 million investigation that NIST proposes to conduct into the World Trade Center disaster, with particular attention to the following: How will the investigation differ from, and follow up on the Federal Emergency Management Agency's BPAT study of the WTC disaster?

The Committee also requested that he describe NIST's proposal to follow the investigation with additional research, with particular attention to:

- How will NIST's proposed research program differ from the investigation?
- How will the research effort or the investigation lead to changes in building standards, practices and codes?
- What additional authorities, if any, will NIST need in order to conduct a complete and through investigation?
- What specific steps is NIST taking to ensure that NIST communicates its plans to the public and professional communities?

Professor Corbett:

Professor Corbett was asked to evaluate the NIST's proposed study with particular attention to the following questions:

- Based on your current understanding of the areas that NIST plans to cover in its proposed investigation and follow-up research plan, how should NIST ensure that all of the areas (especially ones outside of the Agency's traditional expertise) are adequately addressed in its plan?
- How should NIST implement its investigation to ensure that its conclusions are definitive, defensible, and most useful in helping to improve building codes, fire safety standards, etc?
- What additional authorities, if any, do you think NIST must have in order to conduct a thorough and effective investigation, and why?

6. Appendices

Appendix 1:
Hearing charter: "Learning from 9/11: Understanding the Collapse of the World Trade Center," Committee on Science, U.S. House of Representatives, March 6, 2002.

Appendix 2:
The New York Times article from March 29, 2002: "Towers Withstood Impact, But Fell to Fire, Report Says" by James Glanz and Eric Lipton. p A1.

Appendix 1

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

HEARING CHARTER
Learning from 9/11: Understanding the Collapse of the World Trade Center
Wednesday, March 6, 2002
Noon to 2:00 p.m.
2318 Rayburn House Office Building

1. Purpose

On Wednesday, March 6, at noon the House Committee on Science will hold a hearing on the investigation into the collapse of the World Trade Center (WTC). Witnesses from industry, academia, and government will testify on the catastrophic collapse of the WTC complex and subsequent efforts by federal agencies and independent researchers to understand how the building structures failed and why. By scrutinizing the steel and other debris, blueprints and other documents, and recorded images of the disaster, engineers, designers, and construction professionals may learn valuable lessons that could save thousands of lives in the event of future catastrophes, natural or otherwise.

The Committee plans to explore several overarching questions raised by the collapse and the ensuing investigation:

1. What have we learned about how the federal government investigates catastrophic building collapses, and are any changes warranted?

2. What have we learned about the collapse of the World Trade Center, including which structural elements failed first, and why?

3. How will we know what changes, if any, are warranted in building and fire codes as a result of lessons learned from the World Trade Center's collapse?

4. Has the World Trade Center disaster exposed any gaps in our understanding of buildings and fire, and are changes needed in the federal government's research agenda?

2. Background

At 8:47 a.m. on the morning of September 11, 2001, terrorists crashed a fuel-laden Boeing 767 into the north tower (Tower 1) of the World Trade Center (WTC) complex. Approximately 16 minutes later, a second Boeing 767 slammed into the south tower (Tower 2), exploding upon impact and engulfing several of the building's upper floors in flames. While the performance of both towers exceeded their design specifications – the buildings were designed to withstand the force from the initial impact of a 707 jet – the subsequent structural and fire damage still caused the buildings to fall. Tower 2 collapsed in less than an hour, killing victims trapped above the flames and rescue workers in and around the building. Thirty minutes later, Tower 1 met the same fate. While more than 25,000 people were successfully evacuated from the towers, nearly 3,000 people and emergency responders were killed in the collapses. As the day progressed, the remaining WTC buildings collapsed as well, including Building 7, which burned for 8 hours before crumbling to the ground. Fortunately, the later building collapses produced no casualties.

In the wake of the collapses, search and rescue workers launched an around-the-clock recovery effort to find and recover survivors and victims who perished. To make way, literally tons of twisted steel and fractured concrete were removed from the rubble pile and loaded onto convoys of bulldozers and flatbed trucks to be carried away to recycling plants and landfills.

Researchers also began to respond immediately. Among the first were National Science Foundation (NSF)-funded social scientists and engineers who arrived at the WTC site within 48 to 72 hours after the tragedy to begin collecting data. Similarly, the American Society of Civil Engineers (ASCE) formed a Disaster Response Team within hours of the first plane strike. On September 12th, the Federal Emergency Management Agency (FEMA) and its contractor, Greenhorne and O'Mara, Inc., located in Greenbelt, Maryland, commenced the development of a Building Performance Assessment Team (BPAT; explained more fully on the next page) to conduct a formal analysis of the progressive collapses and produce a report of its findings. A variety of other engineering researchers and professionals, including members of the Structural Engineering Association of New York, also engaged in the monumental task of collecting data that could lead to a better understanding of the collapse of the buildings themselves and to the development of mitigation strategies to prevent a similar tragedy in the future.

Concerns Related to the Engineering Investigation

Though many of the individuals who have participated in the WTC building performance investigation are architects and engineers with experience investigating other structural collapses – including those resulting from natural causes as well as terrorist attacks – nothing had prepared these investigators for a disaster of this magnitude and complexity. Unlike the destruction caused by an earthquake, which may affect several buildings across an expansive area, this disaster involved many buildings and a massive debris pile in a small, confined area. Also unlike most earthquakes, the WTC disaster caused significant casualties and prompted a prolonged search and rescue effort. In addition, the concurrent criminal investigation by the Federal Bureau of Investigation and a separate investigation by the National Transportation Safety Board further frustrated the building performance investigators.

The investigation has been hampered by a number of issues, including:

- **No clear authority and the absence of an effective protocol for how the building performance investigators should conduct and coordinate their investigation with the concurrent search and rescue efforts, as well as any criminal investigation:** Early confusion over who was in charge of the site and the lack of authority of investigators to impound pieces of steel for examination before they were recycled led to the loss of important pieces of evidence that were destroyed early during the search and rescue effort. In addition, a delay in the deployment of FEMA's BPAT team may have compounded the lack of access to valuable data and artifacts.

- **Difficulty obtaining documents essential to the investigation, including blueprints, design drawings, and maintenance records:** The building owners, designers and insurers, prevented independent researchers from gaining access – and delayed the BPAT team in gaining access – to pertinent building documents largely because of liability concerns. The documents are necessary to validate physical and photographic evidence and to develop computer models that can explain why the buildings failed and how similar failures might be avoided in the future.

- **Uncertainty as a result of the confidential nature of the BPAT study:** The confidential nature of the BPAT study may prevent the timely discovery of potential gaps in the investigation, which may never be filled if important, but ephemeral evidence, such as memories or home videotapes, are lost. The confidentiality agreement that FEMA requires its BPAT members to sign has frustrated the efforts of independent researchers to understand the collapse, who are unsure if their work is complementary to, or duplicative of, that of the BPAT team. In addition, the agreement has prevented the sharing of research results and the ordinary scientific give-and-take that otherwise allows scientists and engineers to winnow ideas and strengthen results.

- **Uncertainty as to the strategy for completing the investigation and applying the lessons learned:** The BPAT team does not plan, nor does it have sufficient funding, to fully analyze the structural data it collected to determine the reasons for the collapse of the WTC buildings. (Its report is expected to rely largely on audio and video tapes of the event.) Nor does it plan to examine other important issues, such as building evacuation mechanisms. Instead, FEMA has asked the National Institute of Standards and Technology (NIST) to take over the investigation. Yet so far, NIST has not released a detailed plan describing how it will take over the investigation, what types of analyses it will conduct, how it will attempt to apply the lessons it learns to try to improve building and fire codes, and how much funding it will require.

Role of the Federal Emergency Management Agency

The Federal Emergency Management Agency is charged with supporting the nation's emergency management system. FEMA intervenes at all stages of disaster management including preparation, response, recovery, mitigation, risk reduction, and prevention. In the case of the World Trade Center attack, FEMA dispatched Urban Search and Rescue Teams and established a disaster field office at the site within hours of the first strike to assist in New York City's rescue effort. At the same time, the FEMA Building Performance Assessment Team (BPAT) began their important work of initiating an analysis that could ultimately yield valuable information about the sequence of events and failures that resulted in progressive building collapse.

BPATs are routinely deployed by FEMA following disasters caused by events such as floods and hurricanes. The teams are formed by, and operate under the direction of the Mitigation Directorate's Program Assessment and Outreach Division and comprise such individuals as regional FEMA staff, representatives from state and local governments, consultants who are experts in engineering, design, construction, and building codes, and other technical and support personnel. A contractor for FEMA, Greenhorne & O'Mara, Inc., maintains a roster of hundreds of mitigation specialists from across the United States. BPAT teams are typically deployed within seven days of any disaster event.

Generally, a BPAT conducts field inspections and technical evaluations of buildings to identify design practices, construction methods, and building materials that either failed or were successful in resisting the forces imposed by the event. A major objective of the BPAT's findings and recommendations are aimed at improving design, construction and enforcement of building codes to enhance performance in future disasters. The culmination of the BPAT's efforts is a report that presents the team's observations, conclusions, and recommendations for improving building performance in future natural disasters.

The BPAT team deployed to the WTC site was assembled by the American Society of Civil Engineers and is headed by W. Gene Corley, Ph.D., P.E, Senior Vice President of Construction Technologies Laboratory in Skokie, Illinois. He was also the principal investigator in the FEMA study of Oklahoma City's Murrah Federal Office Building. On September 11th, ASCE, in partnership with a number of other professional organizations, commenced the formation of an independent team of experts to conduct a building performance assessment study at the WTC site as part of ASCE's Disaster Response Procedure. In late September, this team, the ASCE Disaster Response team, was officially appointed as the BPAT team and was funded by FEMA to assess the performance of the buildings and report its findings. The BPAT team received $600,000 in FEMA funding in addition to approximately $500,000 in ASCE in-kind contributions.

Appendix 1

The 23-member BPAT team conducted an analysis of the wreckage on-site, at Fresh Kills Landfill and at the recycling yard from October 7-12, 2001, during which the team extracted samples from the scrap materials and subjected them to laboratory analysis. Why the analysis was conducted only after a delay of three weeks after the attacks remains unclear. Since November, members of the Structural Engineers Association of New York (SEAoNY) have volunteered to work on the BPAT team's behalf and are visiting recycling yards and landfills two to three times a week to watch for pieces of scrap that may provide important clues with regard to the behavior of the buildings.

In the month that lapsed between the terrorist attacks and the deployment of the BPAT team, a significant amount of steel debris – including most of the steel from the upper floors – was removed from the rubble pile, cut into smaller sections, and either melted at the recycling plant or shipped out of the U.S. Some of the critical pieces of steel – including the suspension trusses from the top of the towers and the internal support columns – were gone before the first BPAT team member ever reached the site. Fortunately, an NSF-funded independent researcher, recognizing that valuable evidence was being destroyed, attempted to intervene with the City of New York to save the valuable artifacts, but the city was unwilling to suspend the recycling contract. Ultimately, the researcher appealed directly to the recycling plant, which agreed to provide the researcher, and ultimately the ASCE team and the SEAoNY volunteers, access to the remaining steel and a storage area where they could temporarily store important artifacts for additional analysis. Despite this agreement, however, many pieces of steel still managed to escape inspection.

The BPAT team is expected to release its report in April. Because FEMA requires the members of its BPAT team to sign a confidentiality agreement until the report is released, the exact scope of the report is unknown. But it appears from the role that BPAT teams normally play and general comments ASCE members of the BPAT team have made that the report is likely to include an examination of how the buildings behaved leading up to the collapse, hypotheses for which structural elements failed and thereby initiated the collapse, and recommendations for additional research and analysis.

For example, ASCE has said that the study will rely primarily on audio and video recordings, interviews with survivors, blueprints and design drawings of the World Trade Center, and evidence they or the SEAoNY volunteers have collected from the rubble. The BPAT team has access to more than 120 hours of high quality film footage and audiotapes of 911 communications with trapped victims. The BPAT team initially had difficulty in obtaining building blueprints and design drawings from either the City of New York, the Port Authority, the building owners, or the building designers due primarily to liability concerns on the part of the building owners and insurers. Belatedly, however, the team was provided access to these documents in early January.

ASCE has said that the BPAT study will not include an analysis of the evacuation or rescue procedures and may not be able to validate definitively any of a number of hypotheses regarding the collapse. But because of the confidentiality of the report, it is unclear whether the it will provide answers or simply lay out more questions. It is unknown, for example, to what degree the BPAT report will compare video evidence with that collected from the steel beams from the floors that were hit by the planes.

As a result, independent researchers are unsure how they can contribute to the understanding of how the buildings fell without unnecessarily duplicating work. Others fear that the BPAT's silence on the scope of its report may allow critical aspects of the picture to be missed, and that, by the time the report is released and any such gaps are discovered, the trail of evidence that could provide answers may have grown cold.

The National Science Foundation

Researchers supported by the National Science Foundation are used to mobilizing rapidly after an earthquake and arriving on scene soon after the event to begin collecting data. Recognizing the similarities between the WTC disaster and earthquakes, NSF program managers awarded nearly $300,000 to experienced earthquake researchers, including engineers and social scientists, to begin an analysis of the 9/11 terrorist attacks within 72 hours of the events. In an effort to quickly deploy researchers to the site, awards were made through the Small Grants for Exploratory Research Program, a supplemental award program that enables NSF program managers to award additional support to currently-funded investigators through an abbreviated internal review process (see Appendix A for a list of awards).

The efforts of NSF-funded researchers were impeded by the same obstacles the BPAT team encountered: an inability to examine the steel, either removed from the site during the early search and rescue work or shipped to recycling plants, and the denial of access to building design, construction and maintenance documents. Interestingly, it was an NSF-funded researcher who ultimately negotiated the arrangements by which he and others investigating the disaster were provided access to the remaining pieces of steel at the recycling plant.

To date, the NSF-funded researchers continue to face problems. They continue to be denied access to *important building diagrams and blueprints, and so are unable to complete their analyses or develop the* computer models necessary to better understand the failure of the buildings structural elements. Perhaps more importantly, without these computer models, engineering researchers will be unable to develop effective mitigation strategies.

The National Institute of Standards and Technology

NISTs Building and Fire Research Laboratory carries out research in fire science, fire safety engineering, and structural, mechanical, and environmental engineering. It is the only federal laboratory dedicated to research on building design and fire safety. In the past, the lab has investigated several structural failures using authority Congress made explicit in 1985. (15 U.S.C. 282a). The goals of its previous investigations were to determine the probable technical causes of the failures, examine what lessons could be learned from those determinations, and help develop improved building codes, standards, and practices. The investigations also identified areas of research that needed further study.

Shortly after the attack, NIST appointed an employee of the Building and Fire Research Laboratory to serve on the 23-member BPAT team. While this partnership lent some of NIST's resources and expertise to the BPAT study, NIST did not immediately launch a formal investigation into the technical causes that led to the collapse of the World Trade Center buildings.

NIST believes that the World Trade Center collapse raises difficult and technical questions regarding building codes and standards, justifying the redirection of funds to its building and fire lab. For example, standards for concrete design, building loads, and structural integrity may need revision. In response, NIST has redirected $2 million of its fiscal year 2002 internal discretionary funds to the lab to supplement its current building engineering and standards work. NIST has also requested permission to reprogram from the rest of its laboratories another $2 million in fiscal year 2002 funds for these efforts. The reprogramming request is currently pending before the Office of Management and Budget and will ultimately need approval from Congress. NIST did not need Congressional review to redirect its discretionary funds.

In January, after a delay of three months since the terrorists' attacks, FEMA asked NIST to take over the next phase of the investigation of the collapse. Yet neither NIST nor FEMA has released details as to what that next phase would entail (other than the general outline NIST has provided below). In addition, the Administration has not yet indicated whether FEMA, NIST, or a supplemental funding request to Congress would provide funds for such an investigation, nor has it identified how much it would cost.

Administration officials and outside parties are weighing whether a formal arrangement should be made for NIST to serve as FEMA's research arm in the event of future catastrophic building failures. Currently, there is no formal relationship between the two agencies regarding these matters.

Based on some initial planning, NIST has preliminarily identified the following general areas for investigation:

- Determine technically, why and how the buildings collapsed (WTC 1 and 2, and possibly WTC 7);
- Investigate the technical aspects of fire protection, response, and evacuation, and occupant behavior and response;
- Determine whether state-of-the-art procedures were used in the design, construction, operation, and maintenance of the WTC building;
- Determine whether there are new technologies and procedures emerging that could be employed in the future to reduce the potential risks of collapse; and
- Identify building and fire codes, standards, and practices that warrant revision.

3. Questions

Please see Appendix A for copies of letters to witnesses and the questions each was asked to address in testimony at the hearing.

4. Witnesses

The following witnesses will address the subcommittee:

Mr. Robert Shea, Acting Administrator Federal Insurance and Mitigation Administration, and, Mr. Craig Wingo, Director of Division of Engineering Science and Technology, Federal Emergency Management Administration

Dr. W. Gene Corley, P.E., S.E., American Society of Civil Engineers, Chair of the Building Performance Assessment Team reviewing the WTC disaster

Professor Glenn Corbett, Assistant Professor of Fire Science at John Jay College, New York City

Dr. Abolhassan Astaneh-Asl, Professor, Department of Civil and Environmental Engineering University of California, Berkeley

Dr. Arden Bemet, Director, National Institute of Standards and Technology

5. Additional Reading

Glanz, J. (2001, December 4). Wounded Buildings Offer Survival Lessons. The New York Times, p. F1

Glanz, J., & Lipton, E. (2001, December 25). A National Challenged: The Towers; Experts Urging Broader Inquiry in Towers' Fall. The New York Times, p. A1

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FRIDAY, MARCH 29, 2002

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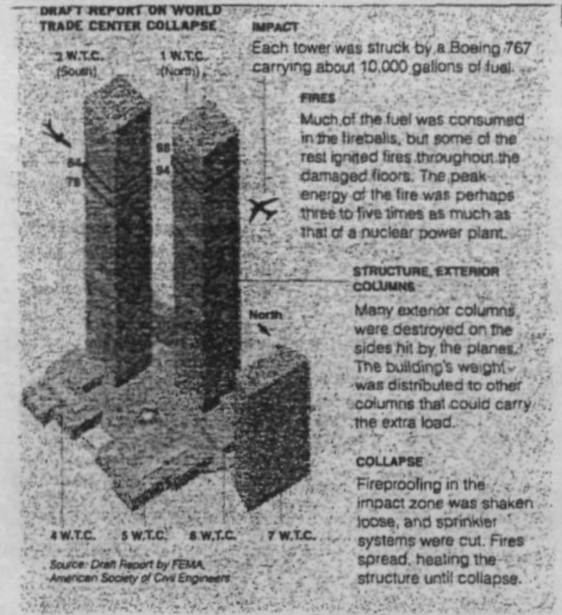


IMPACT
Each tower was struck by a Boeing 767 carrying about 10,000 gallons of fuel.

FIRES
Much of the fuel was consumed in the fireballs, but some of the rest ignited fires throughout the damaged floors. The peak energy of the fire was perhaps three to five times as much as that of a nuclear power plant.

STRUCTURE, EXTERIOR COLUMNS
Many exterior columns were destroyed on the sides hit by the planes. The building's weight was distributed to other columns that could carry the extra load.

COLLAPSE
Fireproofing in the impact zone was shaken loose, and sprinkler systems were cut. Fires spread, heating the structure until collapse.

Source: Draft Report by FEMA, American Society of Civil Engineers

The New York Times; Illustration by John Papasian

Towers Withstood Impact, But Fell to Fire, Report Says

By JAMES GLANZ and ERIC LIPTON

Fireproofing, sprinkler systems and the water supply for hoses all largely failed in the twin towers on Sept. 11 in the face of a blaze so intense that it drove temperatures as high as 2,000 degrees and generated heat equivalent to the energy output of a nuclear power plant, a federal report on how the towers fell has concluded.

The fire, combined with these failures, brought down the towers even after they had shown surprising and lifesaving resiliency to massive structural damage caused by the impact of two hijacked airliners, the report says.

The report's findings detail for the first time the horrific series of events that led to the collapse of two of the world's tallest buildings. They are contained in a draft of a report commissioned by the Federal Emergency Management Agency and the American Society of Civil Engineers.

The draft describes a structure that showed both remarkable strength and critical weaknesses. As was obvious to television viewers worldwide, the towers sustained the initial impact of the planes and were able to redistribute loads away from damaged columns so well that they could probably have remained standing indefinitely if not for the fires, an earthquake or a windstorm, the report said. Team members are still debating the delicate question of whether the tremendous fires could have brought the towers down on their own.

"The ability of the two towers to withstand aircraft impact without immediate collapse was a direct function of their design and construction characteristics, as was the vulnerability of the two towers to collapse as a result of the combined effects of the impacts and ensuing fires," the report concludes.

The report, a copy of which was obtained by The New York Times, is not due to be released officially until late April or early May. It provides documentary evidence that simultaneously supports and rejects many of the theories about what happened to the towers on Sept. 11.

What is already clear is that the jet fuel played a role somewhat different, though still critical, than some experts had speculated. After the planes slammed into the towers,

Continued on Page A14

Death Penalty Sought

The Justice Department said that it would seek the death penalty for Zacarias Moussaoui, the only person arrested in the Sept. 11 attacks. He is charged with conspiring with Osama bin Laden and the Qaeda terrorist network.

Article, Page A14.

A14 YNE THE NEW YORK TIMES, FRIDAY, MARCH 29, 2002

A NATION CHALLENGED: Investigations, Scientific and Criminal

THE TRADE CENTER

Federal Report Says Fire's Intensity Led to the Fall of the Twin Towers

Continued From Page A1

the fireballs that burst over Lower Manhattan consumed perhaps a third of the 10,000 gallons of fuel on board each plane, for example, but did little structural damage themselves, the report says.

Like a giant well of lighter fluid, though, the remaining fuel burned within minutes, setting ablaze furniture, computers, paper files and the planes' cargo over multiple floors and igniting the catastrophic inferno that brought the towers down.

Under normal circumstances, fire suppression systems are designed to allow a high-rise blaze to burn itself out before the building collapses. But the report concludes that there were across-the-board failures in the towers' fire suppression systems, raising disturbing questions about the safety and integrity of other tall buildings in out-of-control fires. But the ultimate significance of those failures is extremely difficult to gauge, the report says, because of the extraordinary circumstances of the attack.

In fact, besides just setting the fires, the impact of the jets may have jarred loose the light, fluffy fireproofing that had been sprayed on steel columns, and flying debris almost certainly sliced through the vertical pipes that supplied water for the hoses and sprinklers.

Because of those uncertainties, the report says, building codes and engineering practices should be studied extensively to consider changes, a step the federal government is already planning, with a $16 million two-year inquiry by the National Institute of Standards and Technology now getting under way. The final version of the FEMA report may recommend specific changes in building codes and standards.

The report is also significant for what it does not include. With the exception of a few contorted steel beams from 5 World Trade Center, a nine-story office building that also burned and suffered localized collapses because the beams failed where they were bolted together, little evidence collected from the piles of debris contributed in a meaningful way to the report's conclusions.

That absence could intensify criticism of an early decision by the city to recycle steel from the trade center rather than make it immediately available for collection and analysis by the research team. About 60 pieces of trade center steel are being sent to the technology institute for the investigation, so future analysis could provide additional answers.

The draft report also does not contain any discussion of what could become a contentious new issue in attempts to explain why the south tower, though struck after the north tower, fell first. That question involves a program, started after the 1993 bombing of the towers, to increase the thickness of the fireproofing on the lightweight steel joists that held up the floors.

At the time of the attack, [illegible] floors on the north tower and 13 floors in the south tower had been upgraded, by increasing the thickness of the fireproofing from three-quarters of an inch to an inch and a half. As it happened, the planes hit floors in the north tower whose fireproofing thickness had already been increased, and floors in the south that had not been upgraded — with one exception, the 78th floor.

Team members are carefully debating what role that difference may have played in the length of time the towers stood after impact: 56 minutes, 10 seconds for the south tower and 102 minutes, 5 seconds for the north. But there are several other possible explanations. The plane that struck the south tower was moving at least 100 miles an hour faster than the other one, heightening the energy upon impact. And it hit 10 floors lower, resulting in far more weight from above bearing down on the damaged area.

Whatever its thickness, much of the fireproofing was probably dislodged by the impact of the planes, the investigators concluded. One official knowledgeable about the fireproofing said the woolly, mineral-based material could be brushed away with the wipe of a finger.

Stripped of its fireproofing, a steel column heats up much more quickly in a fire. The hotter the steel, the less it is able to support loads, as it eventually becomes as soft as licorice. Investigators believe that the structural steel was also greatly imperiled because the sprinklers and standpipes supplying water for firefighting were almost certainly disabled, their supply pipes cut by debris sent flying in the initial crash.

The sprinklers were installed by about 1990 and tanks were stored as high as the 110th floor of the buildings. Witnesses below the areas of impact, and therefore below the primary fires, described water cascading down the stairwells where pipes from those tanks ran. The hoses that firefighters carried on their backs up the same stairwells would therefore have been largely useless, since the standpipes used the same supplies.

The report cites the tight clustering of the exit stairways, three per tower, as a factor that may have made it easier to cause damage to all of them with one blow. These exit stairwells also had relatively lightweight gypsum board sheathing, providing little armor. Partly for these reasons, thousands of people above the floors of impact were trapped.

Most of the tenants in the floors below impact, to the credit of the building and the emergency lighting in the stairwells, escaped. More than 400 firefighters, police officers and other rescue personnel and dozens of tenants who stayed behind during the evacuation were also killed when the buildings finally collapsed. An estimated 2,830 people are considered dead or missing in the collapse.

Against the Manhattan skyline, the gleaming towers looked nearly identical, except for the television tower atop the north tower. But the inquiry found that the forces that toppled them had distinct differences.

Their basic structures before the attacks were extremely similar, even if they were not quite perfect twins. Each tower was supported against the downward force of gravity by a tightly arranged matrix of columns at its core and another palisade of columns, spaced just 40 inches apart, around its exterior.

The core and perimeter columns were connected by lightweight, weblike floor supports called trusses at each floor. The trusses held up corrugated metal decks on which the concrete floors were poured. The same trusses provided lateral support for all the vertical columns, preventing them from buckling under the tremendous force of gravity.

Wide plates called spandrels tied the exterior steel columns together, creating a rigid surface that could resist hurricane-force winds.

These structural elements would become fateful as the jets plowed into the north tower at 8:46 a.m. and the south tower at seconds before 9:03 a.m.

The report — assembled with data collected at ground zero, in scrapyards, in laboratories, by analyzing more than 100 hours of videotape and by talking to witnesses — turned up the greatest amount of detail on the south tower attack.

The United Airlines jet, its wings slightly canted, angled into the south facade of the south tower, slicing through about 30 of the 59 exterior columns on that face. The immediate damage, probably including unseen devastation to the steel core, stretched from the 78th to the 84th floors.

The impact of the plane, which had been traveling as fast as 586 miles an hour, was so great that it gathered office material like a snowplow and apparently forced it toward the northeast corner of the building. Parts of the plane came to rest there and others punctured the far wall, soaring as far as six blocks to the north before hitting the ground near the intersection of Murray and Church Streets.

A fuel-fed fireball emerged from three sides of the tower and consumed roughly one-third of the estimated 10,000 gallons on the plane. Some of the rest flowed down the face of the building and into elevator shafts and stairwells. What remained burned ferociously, setting acres of office space afire as well as the plane's cargo.

The incredible energy generated by this blaze was estimated peak to be three to five gigawatts at its peak. A typical nuclear power plant generates about one gigawatt. All of that energy was converted to deadly heat that began weakening the steel.

WABC

Arrow indicates molten metal, possibly aluminum from the airplane, coming from the south tower just minutes before it collapsed.

Remarkable strength, and critical weaknesses.

But the tower did not fall immediately. Preliminary calculations by the engineering team have revealed that the tight spandrel connections, built to resist the wind, gave the building a remarkable ability to redistribute loads from severed columns to those that remained intact.

This rearrangement was so efficient, the calculations show, that stresses on columns no more than 20 feet from the hole punched in the tower's face were barely higher than what they were before the impact.

But the fires continued to burn. Black smoke poured from shattered windows on floor after floor, fresh oxygen sucked in from the gaping holes caused by the impacts. In the northeast corner of the south tower's 80th floor, where office furniture had been shoved by the plane, the fire burned so hot that a stream of molten metal began to pour over the side like a flaming waterfall.

The apparent source of this waterfall: molten aluminum from the jet's wings and fuselage, which had also piled up in that corner. Within minutes, portions of the 80th floor began to give way, as evidenced by horizontal lines of dust blowing out the side of the building. Seconds later, near the heavily damaged southeasterly portion of this same floor, close to where the aircraft had entered, exterior columns began to buckle.

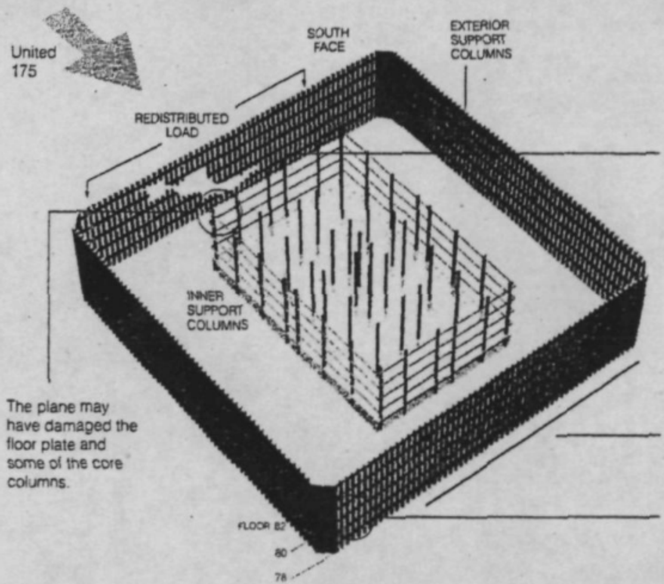
Fifty-six minutes and 10 seconds after it was hit, the top of the south tower tilted horribly, to the east and then to the south, and initiated the collapse of the entire tower, floor upon floor.

Unfolding at a slower pace, the disaster at the north tower will require study before it can be explained in such detail. The plane entered the north tower between the 94th and 98th floors, the report says, destroying about 35 columns on its north face and wreaking indeterminate but probably substantial damage to the core.

The building stood for more than an hour and a half. Videos of the north tower's collapse appear to show that its television antenna began to drop a fraction of a second before the rest of the building. The observations suggest that the building's steel core somehow gave way first, pulling down the rest of the tower with it.

For a few unreal moments, after the north tower had plummeted to the ground, a giant spearlike fragment of the facade remained standing, as if defiantly, looming above the lesser skyscrapers around it. Then the last shard of the tower fell, leaving behind only its arched, cathedral-like base and a narrow trail of smoke to trace its path to the ground.

Appendix 2



The plane may have damaged the floor plate and some of the core columns.

South Tower

IMPACT 9:02:54 a.m.

COLLAPSE 9:59:04 a.m.

Load supported by the destroyed exterior columns was redistributed to adjacent columns, but it is believed that t columns did not exceed their load capacity.

Initially, floors near the impact suffered severe damage across a horizontal span of about 70 feet.

The impact is believed to have disrupted the sprinkler an fire standpipe systems, preventing operation. Even had these systems not been damaged, they would probably have been ineffective, because the initial flash fire would have opened so many sprinkler heads that the systems would have quickly depressurized. Also the fire was so extensive that sprinklers would have been ineffective.

Most intense fires.

A stream of molten material — thought to be aluminum from the plane — flowed down the side of the building.

North Tower

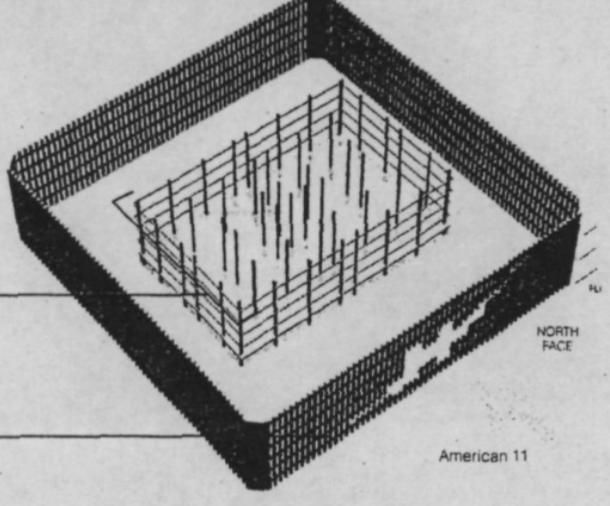
IMPACT 8:46:26 a.m.

COLLAPSE 10:28:31 a.m.

As the plane plowed through the building, it created a cloud of jet fuel that ignited into fireballs, burning an estimated 1,000 to 3,000 gallons of jet fuel. The pressure was sufficient to break windows, but not enough to cause significant structural damage.

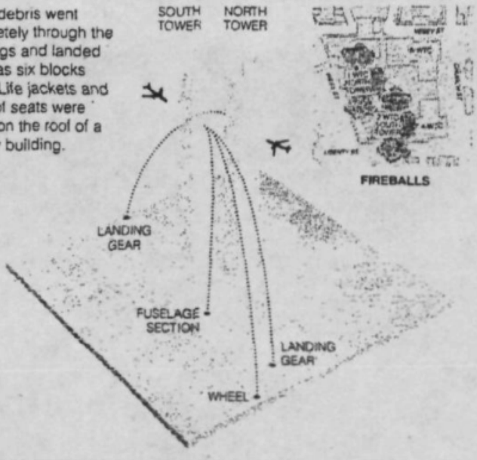
People on the 91st floor described extensive debris in the eastern part of the central core. This suggests a partial collapse of framing in the central core.

Floors supported by the missing sections of exterior walls appear to have partly collapsed across a horizontal span of about 65 feet.



The Impact

Some debris went completely through the buildings and landed as far as six blocks away. Life jackets and parts of seats were found on the roof of a nearby building.



The Collapse

SOUTH TOWER

1. Partial collapse of floor in the southeast corner.

2. Collapse of entire floor along the east side with columns along the east face buckling near the floor, from south to north.

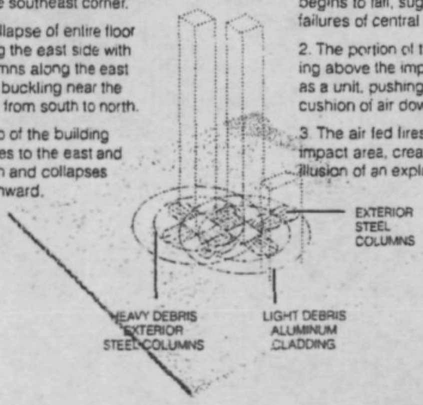
3. Top of the building rotates to the east and south and collapses downward.

NORTH TOWER

1. Television antenna begins to fall, suggestin failures of central colum

2. The portion of the buil ing above the impact fel as a unit, pushing a cushion of air down.

3. The air fed fires in the impact area, creating th illusion of an explosion.


EXTERIOR STEEL COLUMNS
HEAVY DEBRIS EXTERIOR STEEL COLUMNS
LIGHT DEBRIS ALUMINUM CLADDING

Source: Draft report by the Federal Emergency Management Agency

Baden Copeland, Mika Gröndahl, William McNulty, Sarah Slobin and Archie Tse/The New York T

Statement of

Mr. Robert F. Shea
Acting Administrator
Federal Insurance and Mitigation Administration
Federal Emergency Management Agency

Before the

Committee on Science
House of Representatives
United States Congress

March 6, 2002

Mr. Chairman, members of the Committee, I appreciate the opportunity to appear before you today to discuss FEMA's response to the World Trade Center attacks. My name is Robert Shea, Acting Administrator for the Federal Insurance and Mitigation Administration, and I am here representing Joe Allbaugh, the Director of the Federal Emergency Management Agency.

On September 11, 2001, the United States of America was suddenly and savagely attacked by terrorists precipitating the worst disaster in the history of our nation. The tragic loss of life in the collapse of the World Trade Center towers and the destruction at the Pentagon exposed many vulnerabilities to our population and infrastructure within our borders which could be exploited by terrorists and others seeking to harm our country.

Within hours of the terrorist attacks, President Bush had mobilized the Federal government and declared disasters, making Federal support and assistance immediately available to the City and State of New York as well as to the Commonwealth of Virginia. As you know, FEMA helps the nation prepare for, respond to, and reduce the impact of, man-made, natural, and technological hazards including catastrophic events, such as the Alfred P. Murrah Building bombing, the Northridge Earthquake and preparing for Y2K and the Winter Olympics. September 11th was a "wake up" call for our nation and the entire world. In the war on terrorism, FEMA has a clear mission: to make certain that the United States of America becomes "A Nation Prepared".

FEMA's role as an emergency responder was tested but we were able to draw upon decades of experience in hundreds of disasters and the solid relationships that we have forged with States and local governments and other Federal agencies. That experience and those relationships were vital during the first days and weeks following September 11th and enabled FEMA to provide the critical support requested by the City and State of New York to local emergency responders and law enforcement officials. This support included the critical urban search and rescue, debris removal, technical assistance and other emergency measures. The U.S. Fire Administration, an integral part of FEMA, has been providing training to firefighters and emergency responders in initial disaster response and incident command and control -- skills that were fully evident at ground zero.

Under the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended, FEMA has the lead coordination role for Federal disaster response, which is managed through the Federal Response Plan (FRP), involving the 27 Federal agencies, local agencies, and other groups. This national plan, perfected during the last decade, made it possible to effectively support local law enforcement and supplement the response activities undertaken by the City and

State of New York. As for the World Trade Center disaster, the City and State of New York drew upon as many assets as they could, both governmental and private, to rescue and protect their citizens. FEMA has acted in its traditional support role, mindful of the extensive capabilities and the sovereignty of the City and State of New York.

The Federal Response Plan establishes a process and structure for the systematic, coordinated, and effective delivery of supplemental assistance to address the consequences of any major disaster or emergency declared by the President. Within hours of the September 11th attacks, the FEMA Emergency Support Team center was up and running and, implementing the 12 Emergency Support Functions (ESF's) described in the FRP, already coordinating and organizing the Urban Search and Rescue teams, and setting up the Disaster Field Office on-site in New York City.

The most vital Emergency Support Function in response to this tragedy was Urban Search and Rescue (US&R). Because the mortality rate among trapped victims rises dramatically after 72 hours, search and rescue must be initiated without delay. US&R rapidly deploys components of the National US&R Response System to provide specialized lifesaving assistance to State and local authorities in the event of a major disaster or emergency. US&R operational activities include locating, extricating, and providing on-site medical treatment to victims trapped in collapsed structures, and engineering evaluation of structures for safety and building integrity.

A key member of the US&R team is the structural engineer, who must make constant judgments about the structural stability of debris and damaged buildings as the team rescues trapped individuals. As the US&R teams searched through the mountains of twisted steel and concrete, these engineers made safety judgments related to the creation of access points. With engineering expertise coming to New York City from across the country and present within city agencies of New York, the initial response activities were able to pull from an extraordinary pool of local engineering support. During the initial response, engineering support included:

1. Ensuring equipment, such as cranes, was safely located on stable bases to support rescue efforts;
2. Quick and continuing evaluation of the safety of surrounding buildings, infrastructure and the site;
3. Monitoring changes at the site through surveying; and
4. Remote sensing using satellites, and supporting rescue workers on the site by continually reporting this information at shift briefings, site

inspections and visits, and through sophisticated Geographical Information Systems producing up-to-date information and maps.

FEMA's United States Fire Administration also responded to directly assist the New York City Fire Department to re-establish its Incident Command structure, had been tragically lost when the towers collapsed. The forward deployed team assisted in coordinating daily mission planning and logistics for the first three weeks until FDNY was ready to fully resume that role. USFA is also working with the fire department on a training needs analysis to help restore FDNY to its full capacity as it takes on over 400 new firefighters. This, in addition to the US&R, demonstrates FEMA's linkage to the first responders in a catastrophic event.

FEMA's singular goal in the immediate aftermath of the attack was to support local jurisdictions in the rescue of trapped firefighters and workers. As soon as practicable, and without impeding the rescue effort, FEMA began coordinating with State and local governments and private organizations on the next important steps: the short-term and long-term recovery.

FEMA has an established role in recovery: to provide grants to State and local agencies and individuals, as well as coordinating the efforts from other Federal agencies with State, local and charitable organizations in order to help communities and individuals rebuild their lives. Another critical component is the technical assistance that FEMA can bring to bear to not only facilitate a quick recovery but to influence the recovery by giving special consideration to particular aspects of a building or the infrastructure. Although meeting the human needs is paramount, investigating and understanding this enormous and complex disaster can provide benefits for the City of New York's recovery as well as the entire nation.

FEMA has long been an advocate of conducting engineering studies to learn lessons from disasters, whether man-made or natural. In response to hurricanes, floods, earthquakes, and other disasters, including man-made disasters, FEMA often deploys Building Performance Assessment Teams (BPATs) to conduct field investigations at disaster sites. The BPAT is typically employed to determine failure mechanisms of buildings in the aftermath of a disaster so strategies can be developed to increase the disaster-resistance of structures. However, since this event was larger and more complex than any we have ever experienced, the objective of this BPAT is to probe the numerous issues related to structural collapse and fire so that we may make preliminary conclusions and recommendations for more intensive investigation and research.

Immediately following the September 11th attacks, FEMA reached out to the engineering and fire communities to coordinate any post-event studies or evaluations of building performance, incident command, communications or other similar efforts. Within 24 hours, FEMA was in contact with the American Society of Civil Engineers, which was already assembling a team of national experts, drawing talent from a variety of engineering, research and scientific groups that had volunteered to help. This team approach, which is frequently utilized for disasters, has been highly effective for ensuring a multidisciplinary approach with equal voices and inputs from the various sectors. For our World Trade Center evaluation, FEMA and ASCE immediately collaborated on the development of the team analogous to our approach during our study of building performance after the Northridge earthquake. The team of experts was assembled based on what appeared to be the likely failure mechanisms for the World Trade Center towers, namely, fire and structural collapse. There are over twenty national and international experts on this team with knowledge in: building and fire testing; computer modeling of structures and fire; design of tall buildings; steel construction; concrete construction; fire safety; fire protection; and codes and standards. As you know, the National Institute of Standards and Technology (NIST) has a long-established history of investigating building collapses and fires and a mission of research and testing that results in standards and guidance that makes the United States safer and its industries more competitive. FEMA asked NIST to join the BPAT during its formation in September because of NIST's technical expertise and to ensure a smooth transition between FEMA's short-term study and any long-term investigation and research conducted by NIST.

Because of the importance of the rescue effort at the World Trade Center complex, it was clear that information would have to be gathered without interfering with response and rescue activities. Based on this fact, the FEMA-ASCE team first visited the site on October 6, but gathered information from others who had been on-site before this date. This information included plans, photographs, videotapes, eyewitness accounts from rescue workers and reports from the New York City Department of Design and Construction. In addition, the Structural Engineers Association of New York, in support of the City and as a formal member of the BPAT, located and identified specimens of steel for use in future studies. FEMA is coordinating with NIST to make sure that these specimens are properly stored and available for future testing. Also, it is important to note that there are, literally, thousands of plans, specifications and other documents for the World Trade Center. Although it took some weeks to obtain the plans, the owners were fully cooperative with our requests.

Focusing on the areas of fire protection and structural performance, the BPAT team has been gathering evidence and studying designs so that when the report is published, its conclusions and recommendations will help guide future investigative and research efforts connected primarily to understanding the performance of buildings when subjected to extreme conditions.

This study represents an important first step in suggesting how the technical resources of the nation can be brought to bear on protection of lives and property. Because of the importance of this initial report, FEMA and ASCE have compressed in half a schedule that normally takes over a year to complete, which will result in the issuance of a report in early spring. The report will not only make preliminary observations and conclusions about the structural and fire related performance of the World Trade Center towers, but will have six additional chapters that discuss damages and lessons learned from surrounding buildings such as World Trade Center 7, as well as numerous technical appendices.

The National Institute of Standards and Technology (NIST) has the authority and technical expertise to conduct investigative studies of the causes of the collapse and other related matters. The USFA and the Federal Insurance and Mitigation Administration of FEMA will work closely with NIST as it undertakes this ambitious agenda.

USFA will also be looking at the lessons that can be learned from this incident by the nation's first responders. USFA has a long history of doing reports on major incidents and their impacts on the fire service, with a special emphasis on incident command, fire protection systems, evacuation planning and response, communications, and overall fire fighting and rescue response.

Finally, FEMA is currently working with NIST to develop a Memorandum of Understanding (MOU), which will help to guide our future collaborations on similar types of studies. For these types of extreme events, whether natural or man-made, the MOU will serve as a road map to establish protocols for future collaboration of our two agencies under our respective authorities.

I would now be pleased to answer any questions that the Committee may have.

Federal Emergency Management Agency

ABOUT FEMA

HELPING PEOPLE BEFORE, DURING & AFTER DISASTERS

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Robert F. Shea
Acting Administrator
Federal Insurance and Mitigation Administration

Robert F. Shea was appointed Acting Administrator of the Federal Insurance and Mitigation Administration in August 2001 after an agency-wide reorganization. Previously, Mr. Shea was deputy administrator for mitigation in FEMA. In his acting capacity, Mr. Shea is responsible for overseeing the insurance and risk reduction activities of FEMA, including educating residents and state and local official about the importance of risk reduction activities. Mr. Shea also coordinates efforts to educate the public on the importance of insuring property against flood damage.

Previously, Mr. Shea served as the division director for the Program Support Division within FEMA's then-Mitigation Directorate. In that capacity, he provided executive direction to the Hazard Mitigation Planning Program, the Hazard Mitigation Grant Program and the Flood Mitigation Assistance Program.

Mr. Shea has spent 25 years in emergency management in FEMA, serving in various capacities, including chief of the Coordination Office of the former State and Local Program and Support Directorate and chief of the Program Development Division in the former Office of Earthquakes and Natural Hazards.

A native of Atlanta, Ga., Mr. Shea earned bachelor's and masters's degrees in English Literature from The Catholic University of America.

Updated: January 18, 2002

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Testimony of Dr. W. Gene Corley

Senior Vice President
CTL Engineering
Chicago, IL

On behalf of the

American Society of Civil Engineers

Before the
Subcommittee on Environment, Technology and Standards
&
Subcommittee on Research

Committee on Science
U.S. House of Representatives

May 1, 2002

Strathmore
WRITING 25% COTTON

Following the September 11, 2001, attacks on New York City's World Trade Center, the Federal Emergency Management Agency (FEMA) and the Structural Engineering Institute of the American Society of Civil Engineers *(SEI/ASCE),* in association with New York City and several other federal agencies and professional organizations, deployed a team of civil, structural, and fire protection engineers to study the performance of buildings at the World Trade Center (WTC) site.

Founded in 1852, ASCE represents more than 125,000 civil engineers worldwide and is the country's oldest national engineering society. ASCE members represent the profession most responsible for the nation's built environment. Our members work in consulting, contracting, industry, government and academia. In addition to developing guideline documents, state-of-the-art reports, and a multitude of different journals, ASCE, an American National Standards Institute (ANSI) approved standards developer, establishes standards of practice such as the document known as ASCE 7 which provides minimum design loads for buildings and other structures. ASCE 7 is used internationally and is referenced in all of our nation's major model building codes.

The events of following the attacks in New York City were among the worst building disasters and resulted in the largest loss of life from any single building event in the United States. Of the 58,000 people estimated to be at the WTC Complex, over 3,000 lives were lost that day, including 343 emergency responders. Two commercial airliners were hijacked, and each was flown into one of the two 110-story towers. The structural damage sustained by each tower from the impact, combined with the ensuing fires, resulted in the total collapse of each building. As the towers collapsed, massive debris clouds, consisting of crushed and broken building components, fell onto and blew into surrounding structures, causing extensive collateral damage and, in some cases, igniting additional fires and causing additional collapses. In total, 10 major buildings experienced partial or total collapse and 30 million square feet of commercial office space was removed from service, of which 12 million belonged to the WTC complex.

Scope of the study

The purpose of the FEMA/ASCE was to see what could be learned to make buildings safer in the future. Building performance studies are often done when there is major structural damage due to events such as earthquakes or blasts. A better understanding of how building respond to extreme forces can help us design safer structures in the future.

Specifically, the scope of the FEMA/ASCE study was to:

- review damage caused by the attack;
- assess how each building performed under the attack;
- determine how each building collapsed;
- collect and preserve data that may aid in future studies; and
- offer guidelines for additional study.

The team examined:

- The immediate effects of the aircraft impact on each tower;
- The spread of the fire following the crashes;
- The reduction in structural strength caused by the fires;
- The chain of events that led to the collapse of the towers; and
- How falling debris and the effects of the fires impacted the other buildings at the World Trade Center complex.

The team recommendations are presented for more detailed engineering studies, to complete the assessments and produce improved guidance and tools for building design and performance evaluation.

World Trade Center 1 and World Trade Center 2

As each tower was struck, extensive structural damage, including localized collapse, occurred at the several floor levels directly impacted by the aircraft. Despite this massive localized damage, each structure remained standing. However, as each aircraft impacted a building, jet fuel on board ignited. Part of this fuel immediately burned off in the large fireballs that erupted at the impact floors. Remaining fuel flowed across the floors and down elevator and utility shafts, igniting intense fires throughout upper portions of the buildings. As these fires spread, they further weakened the steel-framed structures, eventually triggering total collapse.

The collapse of the twin towers astonished most observers, including knowledgeable structural engineers, and, in the immediate aftermath, a wide range of explanations were offered in an attempt to help the public understand these tragic and unthinkable events. However, the collapse of these symbolic buildings entailed a complex series of events that were not identical for each tower. To determine the sequence of events, likely root causes, and methods or technologies that may improve or mitigate the building performance observed, FEMA and ASCE formed a Building Performance Study (BPS) Team consisting of specialists in tall building design, steel and connection technology, fire and blast engineering, and structural investigation and analysis.

The SEI/ASCE team conducted field observations at the WTC site and steel salvage yards, removed and tested samples of the collapsed structures, viewed hundreds of images of video and still photography, conducted interviews with witnesses and persons involved in the design, construction, and maintenance of each of the affected buildings, reviewed available construction documents, and conducted preliminary analyses of the damage to the WTC towers.

With the information and time available, the sequence of events leading to the collapse of each tower could not be definitively determined. However, the following observations and findings were made:

- The structural damage sustained by each of the two buildings as a result of the terrorist attacks was massive. The fact that the structures were able to sustain this level of damage and remain standing for an extended period of time is remarkable and is the reason that most building occupants were able to evacuate safely. Events of this type, resulting in such substantial damage, are generally not considered in building design, and the fact that these structures were able to successfully withstand such damage is noteworthy.

- Preliminary analyses of the damaged structures, together with the fact the structures remained standing for an extended period of time, suggest that, absent other severe loading events, such as a windstorm or earthquake, the buildings could have remained standing in their damaged states until subjected to some significant additional load. However, the structures were subjected to a second, simultaneous severe loading event in the form of the fires caused by the aircraft impacts.

- The large quantity of jet fuel carried by each aircraft ignited upon impact into each building. A significant portion of this fuel was consumed immediately in the ensuing fireballs. The remaining fuel is believed either to have flowed down through the buildings or to have burned off within a few minutes of the aircraft impact. The heat produced by this burning jet fuel does not by itself appear to have been sufficient to initiate the structural collapses. However, as the burning jet fuel spread across several floors of the buildings, it ignited much of the buildings' contents, permitting fires to evolve across several floors of the buildings simultaneously. The heat output from these fires is estimated to have been comparable to the power produced by a large commercial generating station. Over a period of many minutes, this heat induced additional stresses into the damaged structural frames while simultaneously softening and weakening these frames. This additional loading and damage were sufficient to induce the collapse of both structures.

- The ability of the two towers to withstand aircraft impacts without immediate collapse was a direct function of their design and construction characteristics, as was the vulnerability of the two towers to collapse as a result of the combined effects of the impacts and ensuing fires. Many buildings with other design and construction characteristics would have been more vulnerable to collapse in these events than the two towers, and few may have been less vulnerable. It was not the purpose of this study to assess the code-conformance of the building design and construction, or to judge the adequacy of these features. However, during the course of this study, the structural and fire protection features of the building were examined. The study did not reveal any specific structural features that would be regarded as substandard, and, in fact, many structural and fire protection features of the design and construction were found to be superior to the minimum code requirements.

What caused the collapse of the towers?

Our analysis showed that the impact alone did not cause the collapse of the towers, but instead, left the towers vulnerable to collapse from any significant additional force, such as from high winds, an earthquake, or in the case of the Twin Towers, the fires that engulfed both buildings. Without that second event, the team believes the towers could have remained standing indefinitely.

Although steel is very strong, it loses some of its strength when heated. To prevent that loss of strength, structural steel is protected with fireproofing and sprinkler systems. In the towers, fires raged throughout several floors simultaneously, ignited by the jet fuel and fed by a mixture of paper and furniture. The impact dislodged some fireproofing on the structural beams and columns, which made them vulnerable to fire damage. With the sprinkler systems disabled, the fires raged uncontrollably, weakening the steel and leading to the collapse of the buildings.

Several building design features have been identified as key to the buildings' ability to remain standing as long as they did and to allow the evacuation of most building occupants. These included the following:

- robustness and redundancy of the steel framing system;
- presence of adequate egress stairways that were well marked and lighted; and
- the conscientious implementation of emergency exiting training programs for building tenants.

Similarly, several design features have been identified that may have played a role in allowing the buildings to collapse in the manner that they did and in the inability of victims at and above the impact floors to safely exit. These features should not be regarded either as design deficiencies or as features that should be prohibited in future building codes. Rather, these are features that should be subjected to more detailed evaluation, in order to understand their contribution to the performance of these buildings and how they may perform in other buildings. These include the following:

- the type of steel floor truss system present in these buildings and their structural robustness and redundancy when compared to other structural systems;
- use of impact-resistant enclosures around egress paths;

- resistance of passive fire protection to blasts and impacts in buildings designed to provide resistance to such hazards; and
- grouping emergency egress stairways in the central building core as opposed to dispersing them throughout the structure

Building Codes

During the course of this study, the question of whether building codes should be changed in some way to make future buildings more resistant to such attacks was frequently explored. Depending on the size of the aircraft, it may not be technically feasible to develop design provisions that would enable structures to be designed and constructed to resist the effects of impacts by rapidly moving aircraft, and the ensuing fires, without collapse. In addition, the cost of constructing such structures might be so large as to make this type of design intent practically infeasible.

Although the attacks on the World Trade Center are a reason to question design philosophies, the BPS Team believes there are insufficient data to determine whether there is a reasonable threat of attacks on specific buildings to recommend inclusion of such requirements in building codes. Some believe the likelihood of such attacks on any specific building is deemed sufficiently low to not be considered at all. However, individual building developers may wish to consider design provisions for improving redundancy and robustness for such unforeseen events, particularly for structures that, by nature of their design or occupancy, may be especially susceptible to such incidents. Although some conceptual changes to the building codes that could make buildings more resistant to fire or impact damage or more conducive to occupant egress were identified in the course of this study, the BPS Team felt that extensive technical, policy, and economic study of these concepts should be performed before any specific code change recommendations are developed. This report specifically recommends such additional studies. Future building codes revisions may be considered after the technical details of the collapses and other building responses to damage are better understood.

Surrounding Buildings

Several other buildings, including the Marriott Hotel (WTC 3), the South Plaza building (WTC 4), the U.S. Customs building (WTC 6), and the Winter Garden, experienced nearly total collapse as a result of the massive quantities of debris that fell on them when the two towers collapsed. The St. Nicholas Greek Orthodox Church just south of WTC 2 was completely destroyed by the debris that fell on it.

WTC 5, WTC 7, 90 West Street, 130 Cedar Street, Bankers Trust, the Verizon building, and World Financial Center 3 were impacted by large debris from the collapsing twin towers and suffered structural damage, but arrested collapse to localized areas. The performance of these buildings demonstrates the inherent ability of redundant steel-framed structures to withstand extensive damage from earthquakes, blasts, and other extreme events without progressive collapse.

The debris from the collapses of the WTC towers also initiated fires in surrounding buildings, including WTC 4, 5, 6, 7; 90 West Street; and 130 Cedar Street. Many of the buildings suffered severe fire damage but remained standing. However, two steel-framed structures experienced fire-induced collapse. WTC 7 collapsed completely after burning unchecked for approximately 7 hours, and a partial collapse occurred in an interior section of WTC 5. Studies of WTC 7 indicate that the collapse began in the lower stories, either through failure of major load transfer members located above an electrical substation structure or in columns in the stories above the transfer structure. The collapse of WTC 7 caused damage to the Verizon building and 30 West Broadway. The partial collapse of WTC 5 was not initiated by debris and is possibly a result of fire-induced connection failures. The collapse of these structures is particularly significant in that, prior to these events, no protected steel-frame structure, the most common form of large commercial construction in the United States, had ever experienced a fire-induced collapse. Thus, these events may highlight new building vulnerabilities, not previously believed to exist.

In the study of the WTC towers and the surrounding buildings that were subsequently damaged by falling debris and fire, several issues were found to be critical to the observed building performance in one or more buildings.

General Observations Findings and Recommendations

These issues above fall into several broad topics that should be considered for buildings that are being evaluated or designed for extreme events. It may be that some of these issues should be considered for all buildings; however, additional studies are required before general recommendations, if any, can be made for all buildings. The issues identified from this study of damaged buildings in or near the WTC site have been summarized into the following points:

a. Structural framing systems need redundancy and/or robustness, so that alternative paths or additional capacity is available for transmitting loads when building damage occurs.

b. Fireproofing needs to adhere under impact and fire conditions that deform steel members, so that the coatings remain on the steel and provide the intended protection.

c. Connection performance under impact loads and during fire loads needs to be analytically understood and quantified for improved design capabilities and performance as critical components in structural frames.

d. Fire protection ratings that include the use of sprinklers in buildings require a reliable and redundant water supply. If the water supply is interrupted, the assumed fire protection is greatly reduced.

e. Egress systems currently in use should be evaluated for redundancy and robustness in providing egress when building damage occurs, including the issues of transfer floors, stair spacing and locations, and stairwell enclosure impact resistance.

f. Fire protection ratings and safety factors for structural transfer systems should be evaluated for their adequacy relative to the role of transfer systems in building stability.

What significant recommendations does the team make in its report?

What may be most important is that the BPS Team does not recommend any immediate changes to building codes. The Team believes that there are a number of areas that need further study, and that there are some things that building designers could do to improve safety for occupants in buildings that might be possible terrorist targets.

In general terms, the FEMA/ASCE report suggests that critical building components such as the structural frame, the sprinkler system or the exit stairwells be designed to be more redundant, more robust, or both. Redundancy means, for example, that if some structural columns were shattered, the building would be designed to transfer the weight to other columns. Robustness means making the builder stronger and better able to resist impact without collapse.

The team is also strongly urging additional study of the collapse of the buildings.

What key findings impact all existing buildings?

The team found that some connections between the structural steel beams failed in the fire. This was most apparent in the collapse of World Trade Center Building 5, where the fireproofing did not protect the connections, causing the structure to fail.

The team is calling for more research and analysis of the how the connections weakened and how best to strengthen their resistance to future fires. Typically, fire resistance tests are limited to steel members, not to the steel connections. Furthermore, fireproofing is sprayed on the connections the same way it is applied to the trusses, though the steel in the trusses and joints may be made of different alloys.

Specific Observations, Findings, and Recommendations

The following sections present observations, findings, and recommendations specifically made in each chapter of the FEMA/ASCE report, including the discussion of building codes and fire standards and the limited metallurgical examination of steel from the WTC towers and WTC 7.

Building Codes and Fire Standards

Observations and Findings

a. The decision to include aircraft impact as a design parameter for a building would clearly result in a major change in the design, livability, usability, and cost of buildings. In addition, reliably designing a building to survive the impact of the largest aircraft available now or in the future may not be possible. These types of loads and analyses are not suitable for inclusion in minimum loads required for design of all buildings. Just as the possibility of a Boeing 707 impact was a consideration in the original design of WTC 1 and WTC 2, there may be situations where it is desirable to evaluate building survival for impact of an airplane of a specific size traveling at a specific speed. Although there is limited public information available on this topic, interested building owners and design professionals would require further guidance for application to buildings.

b. The ASTM E119 Standard Fire Test was developed as a comparative test, not a predictive one. In effect, the Standard Fire Test is used to evaluate the relative performance (fire endurance) of different construction assemblies under controlled laboratory conditions, not to predict performance in real, uncontrolled fires.

World Trade Center 1 and World Trade Center 2

Observations and Findings

a. The structural damage sustained by each of the two buildings as aircraft impacted them during the attacks was massive. The fact that the structures were able to sustain this level of damage and remain standing for an extended period of time is remarkable and is the reason that most building occupants were able to evacuate safely. Events of this type, resulting in such substantial damage, are generally not considered in building design, and the ability of these structures to successfully withstand such damage is noteworthy.

b. Preliminary analyses of the damaged structures, together with the fact the structures remained standing for an extended period of time, suggest that absent other severe loading events, such as a windstorm or earthquake, the buildings could have remained standing in their damaged states until subjected to some significant additional load. However, the structures were subjected to a second, simultaneous severe loading event in the form of the fires caused by the aircraft impacts.

c. The large quantity of jet fuel carried by each aircraft ignited upon impact into each building. A significant portion of this fuel was consumed immediately in the ensuing fireballs. The remaining fuel is believed either to have flowed down through the buildings or to have burned off within a few minutes of the aircraft impact. The heat produced by this burning jet fuel does not by itself appear to have been sufficient to initiate the structural collapses. However, as the burning jet fuel spread across several floors of the buildings, it ignited much of the buildings' contents, permitting fires to evolve across several floors of the buildings simultaneously. The heat output from these fires is estimated to have been comparable to the power produced by a large commercial generating station. Over a period of many minutes, this heat induced additional stresses into the damaged structural frames while simultaneously softening and weakening these frames. This additional loading and damage were sufficient to induce the collapse of both structures.

d. Because the aircraft impacts into the two buildings are not believed to have been sufficient to cause collapse without the ensuing fires, an obvious question exists as to whether the fires alone, without the damage from the aircraft impact, would have been sufficient to cause such a collapse. The capabilities of the building fire protection systems make it extremely unlikely that such fires could develop without some unusual triggering event like the aircraft impact. For all other cases, the fire protection for the tower buildings provided in-depth protection. The first line of defense was the automatic sprinkler protection. The sprinkler system was intended to respond quickly and automatically to extinguish or confine a fire. The second line of defense consisted of the manual (FDNY/Port Authority Fire Brigade) firefighting capabilities, which were supported by the building standpipe system, emergency fire department use elevators, smoke control system, and other features. Manual suppression by FDNY was the principal fire protection mechanism that controlled a large fire that occurred in the buildings in 1975. Finally, the last line of defense was the structural fire resistance. The fire resistance capabilities would not be called upon unless both the automatic and manual suppression systems previously described failed. In the incident of September 11, not only did the aircraft impact disable the first two lines of defense, they also are believed to have dislodged fireproofing and imposed major additional stresses on the structural system.

e. Had some other event defeated both the automatic and manual suppression capabilities and a fire of major proportions occurred while the structural framing system and its fireproofing remained intact, the third line of defense, structural fireproofing, would have become critical. The thickness and quality of the fireproofing materials would have been key factors in the rate and extent of temperature rise in the floor trusses and other structural members. In the preparation of this report, there has not been sufficient analysis to predict the temperature and resulting change in strength of the individual structural members in order to approximate the overall response of the structure. Given the redundancy in the framing system and the capability of that system to redistribute load from a weakened member to other parts of the structural system, it is impossible without extensive modeling and other analysis to make a credible prediction of how the building would have responded to an extremely severe fire in a situation where there was no prior structural damage. Such simulations have not been performed within the scope of this study, but should be performed in the future.

f. Buildings are designed to withstand loading events that are deemed credible hazards and to protect the public safety in the event such credible hazards are experienced. Buildings are not designed to withstand any event that could ever conceivably occur, and any building can collapse if subjected to a sufficiently extreme loading event. Communities adopt building codes to help building designers and regulators determine those loading events that should be considered as credible hazards in the design process. These building codes are developed by the design and regulation communities themselves, through a voluntary committee consensus process. Prior to September 11, 2001, it was the consensus of these communities that aircraft impact was not a sufficiently credible hazard to warrant routine consideration in the design of buildings and, therefore, the building codes did not require that such events be considered in building design. Nevertheless, design of WTC 1 and WTC 2 did include at least some consideration of the probable response of the buildings to an aircraft impact, albeit a somewhat smaller and slower moving aircraft than those actually involved in the September 11 events. Building codes do regard fire as a credible hazard and include extensive requirements to control the spread of fire throughout buildings, to delay the onset of fire-induced structural collapse, and to facilitate the safe egress of building occupants in a fire event. For fire-protected steel-frame buildings, like WTC 1 and WTC 2, these code requirements had been deemed effective and, in fact, prior to September 11, there was no record of the fire-induced-collapse of such structures, despite some very large uncontrolled fires.

g. The ability of the two towers to withstand aircraft impacts without immediate collapse was a direct function of their design and construction characteristics, as was the vulnerability of the two towers to collapse as a result of the combined effects of the impacts and ensuing fires. Many buildings with other design and construction characteristics would have been more vulnerable to collapse in these events than the two towers, and few may have been less vulnerable. It was not the purpose of this study to assess the code-conformance of the building design and construction, or to judge the adequacy of these features. However, during the course of this study, the structural and fire protection features of the building were examined. The study did not reveal any specific structural features that would be regarded as substandard, and, in fact, many structural and fire protection features of the design and construction were found to be superior to the minimum code requirements.

h. Several building design features have been identified as key to the buildings' ability to remain standing as long as they did and to allow the evacuation of most building occupants. These include the following:
   - robustness and redundancy of the steel framing system;
   - presence of adequate egress stairways that were; and
   - the conscientious implementation of emergency exiting training programs for building tenants.

i. Similarly, several design features have been identified that may have played a role in allowing the buildings to collapse in the manner that they did and in the inability of victims at and above the impact floors to safely exit. These features should not be regarded either as design deficiencies or as features that should be prohibited in future building codes. Rather, these are features that should be subjected to more detailed evaluation, in order to understand their contribution to the performance of these buildings and how they may perform in other buildings. These include the following:
   - the type of steel floor truss system present in these buildings and their structural robustness and redundancy when compared to other structural systems;
   - use of impact-resistant enclosures around egress paths;

- resistance of passive fire protection to blasts and impacts in buildings designed to provide resistance to such hazards; and
- grouping emergency egress stairways in the central building core, as opposed to dispersing them throughout the structure.

j. During the course of this study, the question of whether building codes should be changed in some way to make future buildings more resistant to such attacks was frequently explored. Depending on the size of the aircraft, it may not be technically feasible to develop design provisions that would enable structures to be designed and constructed to resist the effects of impacts by rapidly moving aircraft, and the ensuing fires, without collapse. In addition, the cost of constructing such structures might be so large as to make this type of design intent practically infeasible.

Although the attacks on the World Trade Center are a reason to question design philosophies, the BPS Team believes there are insufficient data to determine whether there is a reasonable threat of attacks on specific buildings to recommend inclusion of such requirements in building codes. Some believe the likelihood of such attacks on any specific building is deemed sufficiently low to not be considered at all. However, individual building developers may wish to consider design provisions for improving redundancy and robustness for such unforeseen events, particularly for structures that, by nature of their design or occupancy, may be especially susceptible to such incidents. Although some conceptual changes to the building codes that could make buildings more resistant to fire or impact damage or more conducive to occupant egress were identified in the course of this study, the BPS Team felt that extensive technical, policy, and economic study of these concepts should be performed before any specific code change recommendations are developed. This report specifically recommends such additional studies. Future building codes revisions may be considered after the technical details of the collapses and other building responses to damage are better understood.

Recommendations
The scope of this study was not intended to include in-depth analysis of many issues that should be explored before final conclusions are reached. Additional studies of the performance of WTC 1 and WTC 2 during the events of September 11, 2001, and of related building performance issues should be conducted. These include the following:

a. During the course of this study, it was not possible to determine the condition of the interior structure of the two towers, after aircraft impact and before collapse. Detailed modeling of the aircraft impacts into the buildings should be conducted in order to provide understanding of the probable damage state immediately following the impacts.

b. Preliminary studies of the growth and heat flux produced by the fires were conducted. Although these studies provided useful insight into the buildings' behavior, they were not of sufficient detail to permit an understanding of the probable distribution of temperatures in the buildings at various stages of the event and the resulting stress state of the structures as the fires progressed. Detailed modeling of the fires should be continued and should be combined with structural modeling to develop specific failure modes likely to have occurred.

c. The floor framing system for the two towers was very complex and substantially more redundant than typical bar joist floor systems. Detailed modeling of these floor systems and their connections should be conducted to understand the effects of localized overloads and failures to determine ultimate failure modes. Other types of common building framing should also be examined for these effects.

d. The fire-performance of steel trusses with spray-applied fire protection, and with end restraint conditions similar to that present in the two towers, is not well understood, but is likely critical to the building collapse. Studies of the fire-performance of this structural system should be conducted.

e. Observations of the debris generated by the collapse and of damaged adjacent structures suggests that spray-applied fireproofing may be vulnerable to mechanical damage from blasts and impacts. This vulnerability is not well understood. Tests of these materials should be conducted to understand how well they withstand such mechanical damage and to determine whether it is appropriate and feasible to improve their resistance to such damage.

f. In the past, tall buildings have occasionally been damaged, typically by earthquakes, and experienced collapse within the damaged zones. Those structures were able to arrest collapse before they progressed to a state of total collapse. The two WTC towers were able to arrest collapse from the impact damage but not from the resulting fire when combined with the impact effects of the aircraft attack. Studies should be conducted to determine, given the great size and weight of the two towers, whether there are feasible design and construction features that would permit such buildings to arrest or limit a collapse, once it began.

World Trade Center 3

Observations

WTC 3 was subjected to extraordinary loading from the impact and weight of debris from the two adjacent 110-story towers. It is noteworthy that the building resisted both horizontal and vertical progressive collapse after the collapse of WTC 2. The overloaded portions were able to break away from the rest of the structure without pulling it down and the remaining structural system was able to remain stable and support the debris load. The structure was even capable of protecting occupants after the collapse of WTC 1.

Recommendations

WTC 3 should be studied further to understand how it resisted progressive collapse.

World Trade Center 7

Observations and Findings

a. This office building was built over an electrical substation and a power plant, comparable in size to that operated by a small commercial utility. It also had a significant amount of diesel oil storage and had a structural system with numerous horizontal transfers for gravity and lateral loads.

b. The loss of the east penthouse on the videotape records suggests that the collapse event was initiated by the loss of structural integrity in one of the transfer systems. Loss of structural integrity was likely a result of weakening caused by fires on the 5th to 7th floors. The specifics of the fires in WTC 7 and how they caused the building to collapse remain unknown at this time. Although the total diesel fuel on the premises contained massive potential energy, the best hypothesis has only a low probability of occurrence. Further research, investigation, and analyses are needed to resolve this issue.

c. The collapse of WTC 7 was different from that of WTC 1 and WTC 2. The towers showered debris in a wide radius as their external frames essentially "peeled" outward and fell from the top to the bottom. In contrast, the collapse of WTC 7 had a relatively small debris field because the facade came straight down, suggesting an internal collapse. Review of video footage indicates that the collapse began at the lower floors on the east side. Studies of WTC 7 indicate that the collapse began in the lower stories, either through failure of major load transfer members located above an electrical substation structure or in columns in the stories above the transfer structure. Loss of strength due to the transfer trusses could explain why the building imploded, with collapse initiating at an interior location. The collapse may have then spread to the west, causing interior members to continue collapsing. The building at this point may have had extensive interior structural failures that then led to the collapse of the overall building, including the cantilever transfer girders along the north elevation, the strong diaphragms at the 5th and 7th floors, and the seat connections between the interior beams and columns at the building perimeter.

Recommendations

The scope of this study was not intended to include in-depth analysis of issues. Certain issues should be explored before final conclusions are reached and additional studies of the performance of the WTC 7 building and related building performance issues should be conducted. These include the following:

a. Additional data should be collected to confirm the extent of the damage to the south face of the building caused by falling debris.

b. Determination of the specific fuel loads, especially at the lower levels, is important to identify possible fuel supplied to sustain the fires for a substantial duration. Areas of interest include storage rooms, file rooms, spaces with high-density combustible materials, and locations of fuel lines. The control and operation of the emergency power system, including generators and storage tanks, needs to be thoroughly understood. Specifically, the ability of the diesel fuel pumps to continue to operate and send fuel to the upper floors after a fuel line is severed should be confirmed.

c. Modeling and analysis of the interaction between the fire and structure are important. Specifically, the anticipated temperatures and duration of the fires and the effects of the fires on the structure need to be examined with an emphasis on the behavior of transfer systems and their connections.

d. Suggested mechanisms for a progressive collapse should be studied and confirmed. How the collapse of an unknown number of gravity columns brought down the whole building should be explained.

e. The role of the axial capacity between the beam-column connection and the relatively strong structural diaphragms may have had in the progressive collapse should be explained.

f. The level of fire resistance and the ratio of capacity-to-demand required for structural members and connection deemed to be critical to the performance of the building should be studied. The collapse of some structural members and connections may be more detrimental to the overall performance of the building than other structural members. The adequacy of current design provisions for members whose failure could result in large-scale collapse should also be studied.

Recommendations for Future Study

The Building Performance Study Team has developed recommendations for specific issues, based on the study of the performance of the WTC towers and surrounding buildings in response to the impact and fire damage that occurred. These recommendations have a broader scope than the important issue of building concepts and design for mitigating damage from terrorist attacks, and also address the level at which resources should be expended for aircraft security, how the fire protection and structural engineering communities should increase their interaction in building design and construction, possible considerations for improved egress in damaged structures, the public understanding of typical building design capacities, issues related to the study process and future activities, and issues for communities to consider if they are developing emergency response plans that include engineering response.

National Response. Resources should be directed primarily to aviation and other security measures rather than to hardening buildings against airplane impact. The relationship and cooperation between public and private organizations should be evaluated to determine the most effective mechanisms and approaches in the response of the nation to such disasters.

Interaction of Structural Elements and Fire. The existing prescriptive fire resistance rating method (ASTM E119) does not provide sufficient information to determine how long a building component can be expected to perform in an actual fire. A method of assessing performance of structural members and connections as part of a structural system in building fires is needed for designers and emergency personnel.

The behavior of the structural system under fire conditions should be considered as an integral part of the structural design. Recommendations are to:

- Develop design tools, including an integrated model that predicts heating conditions produced by the fire, temperature rise of the structural component, and structural response.
- Provide interdisciplinary training in structures and fire protection for both structural engineers and fire protection engineers.

Performance criteria and test methods of fireproofing materials relative to their durability, adhesion, and cohesion when exposed to abrasion, shock, vibration, rapid temperature rise, and high temperature exposures need further study.

Interaction of Structural and Fire Professionals in Design. The structural, mechanical, architectural, fire protection, blast, explosion, earthquake, and wind engineering communities need to work together to develop guidance for vulnerability assessment, retrofit, and design of concrete and steel structures to mitigate or reduce the probability of progressive collapse under single- and multiple-hazard scenarios.

An improved level of interaction between structural and fire protection engineers is encouraged. Specific recommendations are to:

- Consider behavior of the structural system under fire as an integral part of the design process.
- Provide cross-training of fire protection and structural engineers in the performance of structures and building fires.

Fire Protection and Engineering Discipline. The continued development of a system for performance- based design is encouraged. This involves the following:

- Improve the existing models that simulate fire and spread in structures, as well as the impact of fire and smoke on structures and people.
- Improve the database on material burning behavior.

Building Evacuation. The following topics were not explicitly examined during this study, but are recognized as important aspects of designing buildings for impact and fire events. Recommendations for further study are to:

- Perform an analysis of occupant behavior during evacuation of the buildings at WTC to improve the design of fire alarm and egress systems in high-rise buildings.

- Perform an analysis of the design basis of evacuation systems in high-rise buildings to assess the adequacy of the current design practice, which relies on phased evacuation.
- Evaluate the use of elevators as part of the means of egress for mobility impaired people as well as the general building population for the evacuation of high-rise buildings. In addition, the use of elevators for access by emergency personnel needs to be evaluated.

Emergency Personnel. One of the most serious dangers firefighters and other emergency responders face is partial or total collapse of buildings. Recommended steps to provide better protection to emergency personnel are:

- Have fire protection and structural engineers assist emergency personnel in developing broader pre- plans for buildings and structures to include more detailed assessments of hazards and response of structural elements and performance of buildings during fires, including identification of critical structural elements.
- Develop training materials and courses for emergency personnel with regards to effects of fire on steel.
- Review collaboration efforts between the emergency personnel and engineering professions so that engineers may assist emergency personnel in assessments during the time of the incident.

Education of Stakeholders. Stakeholders (e.g., owners, operators, tenants, authorities, designers) should be further educated about building codes, the minimum design loads typically addressed for building design, and the extreme events that are not addressed by building codes. Should stakeholders desire to address events not addressed by the building codes, they should have a basic understanding of developing and implementing strategies to mitigate damage from extreme events.

Stakeholders should also be educated about the expected performance of their building when renovations, or changes in use or occupancy, occur and the building is subjected to different floor or fire loads. For instance, if the occupancy in a building changes to one with a higher fire hazard, they should review the fire protection systems to ensure there is adequate fire protection. Or, if the structural load is increased with a new occupancy, the structural support system should be reviewed to ensure it can carry the new load.

Study Process. The report benefited from a tremendous amount of professional volunteerism due to the unprecedented level of national disaster. Improvements can be made that would aid the process for any future efforts. Recommendations are to:

- Provide resources that are proportional to the required level of effort.
- Provide better access to data, including building information, interviews, samples, site photos, and documentation.

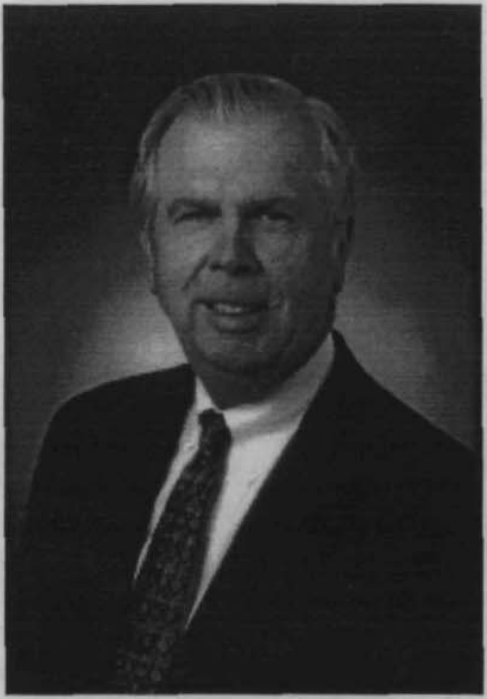
Archival Information. Archival information has been collected and provides the groundwork for continued study. It is recommended that a coordinated effort for the preservation of this and other relevant information be undertaken by a responsible organization or agency, capable of maintaining and managing such information. This effort would include:

- cataloging all photographic data collected to date;
- enhancing video data collected for both quality and timeline;
- conducting interviews with building occupants, witnesses, rescue workers and any others that may provide valuable information; and
- initiating public requests for information.

Conclusion

ASCE is proud of the work done by the BPS Team, but strongly believes that the follow up studies recommended by the FEMA/ASCE Report are critical to obtaining the technical knowledge needed by engineers for future building design.

Thank you for the opportunity to express ASCE's views. We offer you and all of the agencies involved in the recovery efforts ASCE's full resources to manage the nation's critical infrastructure needs. We are ready to help in any way possible, and are eager to hear from you regarding ways that ASCE's Critical Infrastructure Response Initiative can support you as you examine our infrastructure needs in the coming months.



○ W. Gene Corley

Senior Vice President
(b)(6)@ c-t-l.com

Educational Background •

University of Illinois
B.S. Civil Engineering, (b)(6)
M.S. Structural Engineering, (b)(6)
Ph.D. Structural Engineering,

Registration •

Licensed Structural Engineer - Illinois
Licensed Professional Engineer - Illinois
Registered Civil Engineer - California, Hawaii
Registered Professional Engineer - Alabama, Florida, Kansas, Louisiana, Michigan, Mississippi, Missouri, Pennsylvania, South Dakota, Tennessee, Texas, Utah, Virginia, Washington
Chartered Engineer, FI Struct E, UK

CTL Experience • Dr. Corley has served as CTL Vice President since 1987. In this position, he serves as CTL's managing agent for professional and structural engineering and leads structural evaluation projects related to industrial, transportation and parking facilities, bridges and buildings. He also is active in projects related to earthquake engineering. His wide range of experience includes evaluation of earthquake and blast damaged buildings and bridges; investigation of distress in prestressed concrete structures; repair of parking garages damaged by corrosion; evaluation and repair of high rise buildings, stadiums, silos and bridges; design and construction of repairs for prestressed and conventionally-reinforced, precast and cast-in-place concrete and structural steel facilities. In 1995, Dr. Corley was selected by ASCE to lead a Building Performance Assessment Team investigating the bombing of the Murrah Federal Building in Oklahoma City.

Prior Experience • After receiving his B.S. degree, Dr. Corley worked for the Shelby County, Illinois highway department where he designed highways and bridges. He then returned to the University of Illinois as a research assistant and National Science Foundation teaching fellow while pursuing his graduate studies.

Upon completion of his Ph.D., he served as a commissioned officer in the U.S. Army from 1961 until 1964. During this period, Dr. Corley was a research and development coordinator with the U.S. Army Corps of Engineers at Fort Belvoir, Virginia. His duties included bridge design, acceptance testing of mobile floating assault bridge equipment, design of tank launched bridges and fatigue testing of bridges fabricated from high strength steel, aircraft aluminum and titanium alloys.

In 1964, Dr. Corley began work as a development engineer with the Portland Cement Association. While serving in successively more responsible positions, he was directly involved in the development of improved design procedures for structural concrete, concrete pavement, railroads and structures subjected to fire loads. In addition, he served on an earthquake damage investigation team, carried out investigations of damaged or deteriorated structures and developed repair procedures for numerous buildings and bridges.

Publications and Professional Activities • W. Gene Corley has authored more than 150 technical papers and books. He frequently lectures to technical and non-technical groups on the subjects of prevention of failures, effects of earthquakes and design and repair of structures. He regularly presents training courses on reinforced concrete design and teaches the seismic design portion of a refresher course to candidates for the Illinois Structural Engineering License examination.

Dr. Corley chaired ACI Committee 318 for six years as the committee developed the 1995 Building Code Requirements for Structural Concrete. He also serves on several other national and international committees that prepare recommendations for structural design and for design of earthquake resistant buildings and bridges. His professional activities resulted in his receiving 11 national awards including the Best Structural Publication Award from NCSEA, Outstanding Paper from the ASCE Journal of Performance of Constructed Facilities, the Wason Award for research from ACI, the T.Y. Lin Award from ASCE and the Martin Korn Award for PCI. He also has received several regional awards, including the UIUC Civil Engineering Alumni Association's Distinguished Alumnus Award, the SEAOI Service Award, Illinois ASCE Structural Division's Lifetime Achievement Award, the Henry Crown Award, and the SEAOI John Parmer Award.

Dr. Corley serves or has served in leadership roles for numerous professional organizations, both national and international, including the following:

American Society of Civil Engineers (Fellow)
National Society of Professional Engineers (Member)
National Council of Structural Engineers Associations (Founding Member, Board of Direction, Former President)
American Concrete Institute (Fellow) Former Chairman, Committee on Standard Building Code
American Railway Engineering Association (Member)
Building Seismic Safety Council (Former Vice-Chairman and Founding Member, Board of Direction)
Chicago Committee on High Rise Buildings (Member and Former Chairman)
Earthquake Engineering Research Institute (Member and Former President, Great Lakes Chapter)
Institution of Structural Engineers, UK (Fellow)
International Association for Bridge and Structural Engineering (Member)
National Academy of Engineering (Member)
National Association of Railroad Safety Consultants and Investigators (Member)
NACE International (Member)
Prestressed Concrete Institute (Member)
RILEM (Member)
Post Tensioning Institute (Member)
Transportation Research Board (Member)
Structural Engineers Association of Illinois (Member, Former President)
Governor's Earthquake Preparedness Task Force (Illinois)

Testimony of Dr. Arden L. Bement, Jr.
Director

National Institute of Standards and Technology
Technology Administration
U.S. Department of Commerce

Before The
House Science Committee

Hearing on
"The Investigation of the World Trade Center Collapse:
Findings, Recommendations and Next Steps"

May 1, 2002

Chairman Boehlert, Ranking Member Hall, and Members of the Committee, I want to thank you for this opportunity to testify on the National Institute of Standards and Technology's proposed investigation into the collapse of the World Trade Center (WTC) buildings.

I will outline the proposed ***NIST response plan*** today, and show how it complements and is responsive to the efforts of the Building Performance Assessment Team, or BPAT, led by the American Society of Civil Engineers (ASCE) and sponsored by the Federal Emergency Management Agency, FEMA. The response plan addresses all major recommendations contained in the BPAT report. I commend Dr. Gene Corley and the BPAT members for their excellent report and detailed recommendations. The National Institute of Standards and Technology (NIST) has also identified other critical issues that need study, especially in areas that impact life safety and engineering practice.

The NIST proposed response plan consists of three key program elements – including an investigation – to be conducted in parallel *(graphic to be projected on video monitors).* These are:

- First, a 24-month ***building and fire safety investigation*** into the collapse of the Twin Towers (WTC 1 and 2) and WTC 7. The goal of this program element is to investigate the building construction, the materials used, and the technical conditions that combined to cause these disasters following the initial impact of the aircraft. While WTC 4, 5,and 6 will not be investigated specifically in this phase, what we learn in examining WTC 1, 2 and 7 would benefit buildings of all designs.

- Second, a multi-year ***research and development (R&D) program*** to provide the technical basis to support improved building and fire codes, standards, and practices. This program element addresses work in critical areas such as structural fire safety, prevention of progressive collapse, and equipment standards for first responders. It includes BPAT recommendations for WTC 3, 4, 5, and 6, Bankers Trust, and peripheral buildings as well as recommendations for future studies to address specific issues of broader scope not covered by the BPAT. The program outputs and recommendations will support the voluntary consensus process that is used to develop building and fire codes and standards in the United States.

- Third, an industry-led ***dissemination and technical assistance program (DTAP)*** that will provide practical guidance and tools to better prepare facility owners, contractors, designers, and emergency personnel to respond to future disasters. The DTAP will also be an important complement to the R&D effort to demonstrate and gain acceptance of proposed changes to practice, standards, and codes. This program element addresses BPAT recommendations for the training and education of stakeholders.

All the BPAT recommendations can be seen to map into the three above elements in this graphic *(graphic on screen).*

We have shared the overall response plan approach extensively with public and private sector organizations and have welcomed their inputs since the middle of October 2001. The plan was modified in January 2002 when FEMA requested NIST to initiate an investigation under NIST's unique legislative authorities to conduct structural and fire investigations. This request was in direct response to a growing demand for a broad-based federal investigation into the World Trade Center disaster from technical experts, industry leaders, and families of building occupants and first responders who lost their lives on September 11, 2001. We continue to revise the plan as more technical information becomes available and to be responsive to the suggestions and needs of these many stakeholders.

The Commerce Department and NIST have received letters supporting our proposed response plan from key industry leaders responsible for U.S. building and fire standards, codes, and practices, including the American Society of Civil Engineers, the National Fire Protection Association, the American Institute of Architects, the Council on Tall Buildings and Urban Habitat, the Construction Industry Institute, the Society of Fire Protection Engineers, and the International Association of Fire Chiefs.

We agree with the BPAT recommendations that additional study of the Twin Towers and WTC 7 should be conducted. The NIST investigation will focus on these buildings. We believe strongly that the results of such an investigation could lead to major changes in both U.S. building *and* fire codes and in engineering practice, despite the unique design features or circumstances under which the buildings collapsed. We also believe strongly that the lessons to be derived from such an investigation will be applicable to a broad range of buildings types, not just the specific buildings that are studied. Let me now give you some examples to illustrate why we believe this to be the case.

The Twin Towers and WTC 7 are the only known cases of total structural collapse where fires played a significant role. These disasters provide a unique source of information to understand the complexities associated with the dynamics of real building fires and the collapse vulnerability of buildings to fires. We expect to analyze that information to validate generally applicable methodologies for use in fire safety design and retrofit of structures, and to evaluate the performance of fireproofing materials and connections used in steel structures.

In addition, these building disasters provide a unique source of information to study:

- The safety and performance of open-web steel trussed joists under fires. This type of trussed joist is used widely in floor and roof systems for commercial and institutional buildings nationwide.
- New mechanisms – not considered previously – that could initiate progressive collapse in buildings as a result of fires and impact loads, including the critical role of pivotal components such as transfer girders and floor diaphragms.
- The mechanical and metallurgical behavior of many different grades of structural steel under fires using steel recovered from the WTC site that is being stored at NIST.

There are equally important lessons for life safety – which were outside the scope of the BPAT study:

- Firefighting technologies and practices for tall buildings, including occupant behavior, evacuation, emergency response, and the performance of built-in fire protection systems such as sprinklers and fire alarms.

- The control of fire spread in buildings with large open floor plans, and the effectiveness of compartmentation as a means to isolate fires in such buildings.

There are also important lessons to be learned for engineering practice – areas that were not the focus of the BPAT study:
- The performance of the design, construction, and approval processes used to assure safety whenever an innovative structural system is used or there is a need for variances from building and fire codes.
- The provision of adequate structural reserve capacity to accommodate abnormal loads such as blast, impact, and accidental fires – especially those that can be anticipated prior to construction – balanced properly against the need to achieve design efficiency.

The proposed NIST investigation will include world-class technical expertise from both within and outside NIST. External experts will be drawn from both academia and practice and several of those may well have contributed to the BPAT study.

We propose to charter a Federal Advisory Committee to guide all aspects of the NIST investigation, including the review of major investigation reports. Members of this group will be recognized for their distinguished professional service, possess broad technical expertise and experience, and have a reputation for independence, objectivity, and impartiality.

I have appointed a Secretariat within NIST to coordinate NIST-level activities in support of the WTC investigation and to maintain ongoing liaison with members of Congress, the public, and the media.

NIST will assign a special liaison to interact with the families of building occupants and first responders. We recognize the vital role that those individuals and groups have to play in providing input on the scope of the proposed NIST investigation. We also understand that it is appropriate and important to keep these families and organizations informed about the progress of the proposed investigation.

We will maintain ongoing liaison with the professional communities over the course of the investigation through periodic briefings, presentations, and opportunity for comment on key investigation reports.

A summary of the proposed NIST investigation plan is attached for the record and is being made available to the general public on the NIST website beginning today. NIST will use an open and inclusive process in planning and conducting the investigation, and in publishing its findings and recommendations. We consulted extensively with technical experts and groups in developing the plan and briefed the BPAT experts at their January 2002 meeting, and again last Wednesday. Yesterday, we briefed representatives of the parent organizations comprising the BPAT coalition. We will hold a public meeting in New York City in the near future to share the details of the proposed NIST plan, which will be made available to the general public two weeks prior, and seek the public's informed comment on its scope before we adopt the plan as final.

Following our statutory requirements, before we begin a building investigation, we consult with local authorities. In this case, we consulted with local authorities in New York, including the Port Authority of New York and New Jersey, the Mayor's Office of Emergency Management, the New York City Department of Design and Construction, and the Fire Department of New York. These organizations have expressed written support for NIST and agreed to cooperate in its investigation.

The Administration has expressed strong commitment for the NIST response plan and has requested $16 million as part of the Federal Emergency Management Agency's FY 2002 supplemental budget request – now in Congress – to support the NIST investigation. The President's FY 2003 budget request to Congress also requests an increase of $2 million in base funding to support other elements of the NIST response plan. The Building and Fire Research Laboratory within NIST has already redirected approximately $2 million of its existing base funds to support the response plan. Future resource requirements for the broader research and development and dissemination and technical assistance program will be considered in the Fiscal Year 2004 budget process and beyond.

Finally, Mr. Chairman, I look forward to working with you and members of this Committee as NIST embarks on a very important technical investigation. FEMA and NIST are committed to ensuring a smooth transition. Mr. Robert Shea and I recently signed a Memorandum of Understanding to strengthen our collaborative bonds by designating NIST to serve as a research and technical resource for FEMA. With your permission, I would like to submit a copy of that MOU for the record. We have agreed to develop and sign, by the end of May 2002, an operational protocol for a quick deployment mechanism that could be activated when a NIST response to extreme events is needed.

This concludes my prepared remarks. I will be pleased to answer your questions.

Arden L. Bement, Jr., Director

Purdue University News Service

Arden L. Bement, Jr., was sworn in as the 12th director of NIST on Dec. 7, 2001. *Bement oversees an agency with an annual budget of about $812 million and an* onsite research and administrative staff of about 3,000, complemented by a NIST-sponsored network of 2,000 locally managed manufacturing and business specialists serving smaller manufacturers across the United States. Prior to his appointment as NIST director, Bement served as the David A. Ross Distinguished Professor of Nuclear Engineering and head of the School of Nuclear Engineering at Purdue University. He has held appointments at Purdue University in the schools of NuclearEngineering, Materials Engineering, and Electrical and ComputerEngineering, as well as a courtesy appointment in the KrannertSchool of Management. He was director of the MidwestSuperconductivity Consortium and the Consortium for the IntelligentManagement of the Electrical Power Grid.

Bement came to his position as NIST director well versed in the workings of the agency, having previously served as head of the Visiting Committee on Advanced Technology, the agency's primary private-sector policy adviser; as head of the advisory committee for NIST's Advanced Technology Program; and on the Board of Overseers for the Malcolm Baldrige National Quality Award.

Bement joined the Purdue faculty in 1992 after a 39-year career in industry, government, and academia. These positions included: vice president of technical resources and of science and technology for TRW Inc. (1980-1992); deputy under secretary of defense for research and engineering (1979-1980); director, Office of Materials Science, DARPA (1976-1979); professor of nuclear materials, MIT (1970-1976); manager, Fuels and Materials Department and the Metallurgy Research Department, Battelle Northwest Laboratories (1965-1970); and senior research associate, General Electric Co. (1954-1965).

Along with his NIST advisory roles, Bement served as a member of the U.S. National Science Board, the governing board for the National Science Foundation, from 1989 to 1995. He also chaired the Commission for Engineering and Technical Studies and the National Materials Advisory Board of the National Research Council; was a member of the Space Station Utilization Advisory Subcommittee and *the Commercialization and Technology Advisory Committee for* NASA; *and consulted for the* Department of Energy's Argonne National Laboratory and Idaho Nuclear Energy and Environmental Laboratory.

He has been a director of Keithley Instruments Inc. and the Lord Corp. and was a member of the Science and Technology Advisory Committee for the Howmet Corp. (a division of ALCOA).

Bement holds an engineer of metallurgy degree from the Colorado School of Mines, a master's degree in metallurgical engineering from the University of Idaho, a doctorate degree in metallurgical engineering from the University of Michigan, and a honorary doctorate degree in engineering from Cleveland State University. He is a member of the U.S. National Academy of Engineering.

Statement of

Professor Glenn P. Corbett
John Jay College of Criminal Justice

Before the

Committee on Science
House of Representatives
United States Congress

"The Investigation of the World Trade Center Collapse: Findings, Recommendations and Next Steps"

May 1, 2002

Good afternoon Chairman Boehlert, Ranking Member Hall, and Members of the House Science Committee. Thank you for allowing me to again testify before you about the investigation of the World Trade Center disaster.

Nearly eight months have passed since the collapse of the twin towers, yet today we are only just beginning to understand exactly what happened on September 11th at the World Trade Center (WTC). While the Building Performance Assessment Team (BPAT) report that is being released at today's hearing yields some useful information, the generalized nature of its recommendations and the limited scope of the assessment leave us with little hard evidence for which to make specific improvements to codes, design practices, and emergency response procedures. The recommendations of this report provide us with a useful starting point, but much work remains to be done.

The proposed National Institute of Standards and Technology (NIST) investigation that is under consideration today is the type of large-scale forensic inquiry that the federal government should have launched last September. I was pleased to learn that NIST plans to conduct a thorough and comprehensive investigation, incorporating the six focus areas that I identified in my testimony before this Committee on March 6th. They intend to take a multi-disciplinary approach, allowing for the investigation to benefit from the expertise of a wide range of experts and to permit the disaster to be studied holistically. The depth and breadth of the planned investigation will provide as complete an understanding of the disaster at the World Trade Center as is now possible.

The fact-finding "leave no stone unturned" objective of the NIST investigation will allow us to develop detailed conclusions and learn the lessons about what transpired at the World Trade Center. It is the application of these hard-earned lessons, of course, that is the primary reason for conducting the investigation in the first place. These lessons must be translated into actual changes to our building and fire codes, enhancements in building design methodologies, and improvements in emergency response procedures and technologies. While NIST has laid out a comprehensive proposal for investigating and researching the lessons learned from the disaster, the key to achieving this goal lies in the details of the NIST plan. This is where I will focus my comments today.

After having reviewed several draft documents concerning the actual plan for the NIST investigation, I have identified three particular areas of concern: 1) the need for the *rapid* assemblage of a diverse group of individuals to form the core "Federal Advisory Committee" which will oversee the investigation; 2) the need for subpoena power for the investigation; and 3) the need for the investigation to be centered upon the development of "defensible" and detailed proposals for changes in building and fire codes as well as improvements in emergency response procedures and technologies. While I am aware that NIST is attempting to deal with these three issues, I think that it is important to highlight these concerns in light of what has happened in the preparation of the BPAT report.

The Federal Advisory Committee's critical role will be its review of NIST's draft plan for the investigation and in its ongoing role of monitoring the investigation. These duties are very important in light of the multidisciplinary aspects of the investigation and since some areas of the investigation involve issues that are outside of NIST's traditional areas of expertise such as building evacuation, firefighting, and urban search and rescue. It is essential that the Committee is composed of many individuals with a broad range of expertise and experience. It is equally important that the Committee be formed as quickly as possible to allow for the rapid development and implementation of the best plan possible.

A review of NIST's current draft plan has spotlighted the need for the guidance of the "world class experts" of the Federal Advisory Committee. For example, the "evacuation" portion of the draft plan does not propose that individual interviews of survivors be conducted but rather relies on the use of survey forms to collect information. A "one size fits all" survey form will not gather all of the critical information that is necessary to understand the evacuations that took place on September 11th. In order to gain all valuable data including unanticipated information, actual interviews of the survivors must be conducted. In addition, the interview process itself will allow for the presence of a mental healthcare professional who can help the survivor address the emotions that will be unleashed when asking questions about how they survived. Federal Advisory Committee members with expertise in human behavior and building evacuations would be able to provide useful information for the development of such an interview plan as well as the anticipated costs.

This need for diversity of expertise became evident in my review of the BPAT report. For example, the BPAT report recommends the development of "…training materials and courses for emergency personnel with regards to effects of fire on steel." In reality, there are several books and training materials currently available concerning building construction, including large amounts of information on steel frame buildings and the effects of fire on steel. Ironically, FEMA itself (through the United States Fire Administration) publishes a very popular training program called "Principles of Building Construction: Noncombustible." I believe that had a firefighter been on the BPAT team, this fact would have been quickly identified.

The second area of concern is the need for subpoena power. In order to thoroughly investigate the WTC disaster, investigators must have access to all relevant information. It is only with a full set of facts that conclusions may be drawn. The experience in the preparation of the BPAT study has identified this as a key issue. The Science Committee hearing on March 6th clearly highlighted some of the impediments the BPAT faced in obtaining key information. My fear is that the NIST investigation will be hindered by these same problems.

Information may be found in a variety of locations and may be held by many different individuals and organizations that will not provide this information voluntarily. Even though the WTC investigation is an investigation of a fact-finding nature, a legal means for obtaining information that would otherwise be unavailable must be provided for investigators.

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The third area of concern is to learn as many lessons as possible and to apply these lessons. In order for changes related to building and fire codes to be applied, the NIST investigation and research reports must include specific recommended changes to specific sections of our model codes, not generalized recommendations.

For example, in the Observations, Findings, and Recommendations chapter of the BPAT study, the report states "Fireproofing needs to be tough under impact and fire conditions that deform steel members,..." This conclusion will not easily find its way into the model codes since it is not in the proper code format and lacks the corresponding necessary supporting evidence. NIST must recognize this fact if the ultimate goal is to actually improve building codes, standards, and practices.

These proposed changes and related supporting evidence developed by NIST must be laid at the feet of the code-writing organizations for inclusion in their model codes. In addition, I believe that a special, formalized code change submittal process should be developed between NIST and the code-writing bodies to address the code changes that will emerge from this investigation. This more formalized relationship will raise many difficult questions, which are likely outside the scope of this hearing. However, the Science Committee should continue to look into this issue to see what barriers must be overcome.

I believe that the proposed NIST investigation is the best course of action to learn and apply the lessons of the World Trade Center disaster. It is critical that the investigation be as comprehensive as currently planned and be funded at the necessary level to achieve this goal. It is essential that we learn exactly what happened to the structures, victims, and survivors on September 11th and try to prevent it from ever happening again.

Thank you for allowing me to appear before you on this very important topic. I would be happy to answer any questions that you may have.

GLENN P. CORBETT

(b)(6)

Home: (b)(6)
Work:

SUMMARY: Extensive experience in different facets of fire protection including the fields of firefighting and fire prevention. In-depth knowledge of the development and trends of the American fire protection profession.

EXPERIENCE:

January 1995 to Present
John Jay College of Criminal Justice, New York, New York
Assistant Professor of Fire Science
Coordinator, Undergraduate Fire Science Programs
Director, Graduate Protection Management Program (Jan. 1995 – June 1997)

- Prepare and teach fire science courses at the undergraduate and graduate level
- Manage and coordinate course offerings in undergraduate fire science and fire and emergency services programs, including internet offerings
- Provide guidance to existing and prospective fire science students

Sept. 1994 to Dec. 1994
Lecturer, Fire Science

April 1993 to April 1994
PennWell Publishing Company, Saddle Brook, New Jersey
Technical Director, *Industrial Fire Safety* Magazine

- Provided and maintained technical editorial direction of an industrial fire protection and safety magazine, *Industrial Fire Safety*
- Reviewed all articles submitted for publication for accuracy and relevancy

August 1987 to April 1993
San Antonio Fire Department, San Antonio, Texas
Administrator of Engineering Services

- Established Engineering Services Office, including procedures, policies, and the physical plant
- Directed and evaluated staff consisting of fire protection engineer and 3 plan reviewers
- Managed all plan reviews conducted by the department including (annually) 2000 building permits (1500 interior remodels, 500 new structures) and fire protection system plans (500 sprinkler, 350 fire alarm, and other types of systems)
- Coordinated fire prevention activities with other city departments such as Building Inspections and Planning
- Coordinated, prepared, and taught 250+ hour fire inspector training course
- Served/assisted various city committees such as a Development Task Force, Board of Appeals, and Blue Ribbon Fire Department Study
- Provided technical assistance to architects, engineers, developers, and contractors
- Assisted in the preparation of new fire code and amendments

March 1986 to August 1987
Austin Fire Department, Austin, Texas
Fire Protection Engineer

- Reviewed fire protection system plans as well as water supply plans for code compliance
- Assisted uniformed personnel in the review of building permit plans
- Assisted in the preparation of code policy manual for development community
- Responded to multiple alarm fires to provide on-scene technical assistance

1985
A.B.C. Loss and Fire Prevention Corp., East Orange New Jersey
Loss Prevention Consultant

- Estimated and designed automatic sprinkler systems

- Monitored sprinkler system installations and evaluated existing systems

Concurrent
Fire Engineering Magazine, **PennWell Publishing Company**, Fair Lawn, N.J.
Consulting Editor, August 1986 - September 1990
Editorial Advisory Board Member/Columnist, October 1990 - April 1993
Technical Editor/Columnist, April 1993 - Present
Fire Department Instructors Conference Planning Committee member (1997 - present)

1978 - 1986 & 1994 - present
Waldwick Volunteer Fire Department, Waldwick, New Jersey
Volunteer Firefighter (Through Dec. 1995)
Deputy Municipal Fire Coordinator (Jan. 1996 – Aug. 1997)
Second Lieutenant (Sept. 1997 – Dec. 1997)
First Lieutenant (Jan. 1998- Dec. 1998)
Second Captain (Jan. 1999 – Dec. 2001)
First Captain (Jan. 2002 – Present)

1979 - 1986
Paterson Fire Department, Paterson, New Jersey
Auxiliary Firefighter

EDUCATION: Worcester Polytechnic Institute, Worcester Massachusetts
(b)(6) M. Eng., Fire Protection Engineering
Thesis: "Water Supply Evaluation for Firefighting"

John Jay College of Criminal Justice, New York, New York
(b)(6) B.A., Fire Service Administration, Cum Laude
Dean's List, 1979 - 1982

MEMBER:
Bergen County Fire Chief's Association
International Association of Fire Chiefs
International Society of Fire Service Instructors
National Fire Protection Association
New Jersey Society of Fire Service Instructors (currently serving as President)
Society of Fire Protection Engineers

COMMITTEE: "America Burning: Re-commissioned" Panel, appointed By Federal Emergency Management Agency (FEMA) Director James Lee Witt in August 1999

Fire Code Advisory Council, State of New Jersey

CERTIFICATION/LICENSE:
State of Texas:
Professional Engineer's License, (b)(6)
Inactive certification as Class "A" Fire Inspector and Basic Fire Instructor

State of New Jersey:
Firefighter I, (b)(6)
Fire Official

CONGRESSMAN SHERWOOD BOEHLERT (R-NY)
OPENING STATEMENT FOR WORLD TRADE CENTER HEARING
March 7, 2002

I want to welcome everyone to this hearing on a most important, but difficult subject – the investigation into the collapse of the World Trade Center.

It is indeed a difficult subject because it is, at once, emotionally rending and intellectually complex. And it's also difficult because it forces us to cast a critical eye on the dedicated work of public servants and public-spirited volunteers who were taking action amid chaos brought on by an unforeseen and unprecedented tragedy.

But despite these difficulties and the discomfort they may engender, we felt we needed to put together this hearing. The Committee decided to move forward for two fundamental reasons. First, we believe that we owe it to the victims and their families to learn everything possible about what happened in those horrifying first hours of September 11th – not just to satisfy their immediate needs and yearnings, but to ensure that such a catastrophic building failure, and the resulting loss of life, never happen again.

(Review more appropriate)

I must say that the current investigation seems to be shrouded in excessive secrecy. This has unnecessarily increased the families' anxiety while actually complicating the investigation. I hope this hearing, by airing the facts of the investigation, will dispel unnecessary concerns while allowing legitimate ones to be pursued more productively.

But perhaps even more important for the Committee, we need to have this hearing because the Trade Center investigation raises questions about federal responsibilities and federal policies – responsibilities and policies that have broader application than this one terrifying – and, we pray, unique -- incident.

The federal government, as a matter of course, takes on investigations of catastrophic building failures, whatever their cause. That's the only way we, as a nation, can learn from building failures and change our building and fire codes to prevent future ones. Indeed, the engineering of buildings to withstand earthquake damage has improved markedly as a result of federally supported efforts.

Yet in this case, the investigation has faced numerous obstacles. Federal agencies did not coordinate sufficiently, some dragged their feet; no organized team was at the site for weeks; potentially valuable evidence has been lost irretrievably, and blueprints were unavailable for months. What this experience clearly points up is that the federal government needs to put in place standard investigative protocols and procedures right now, so we don't have to "reinvent the wheel" each time we face a building failure. That's one change in federal policy that ought to result from the World Trade Center experience.

Another significant lesson of the Trade Center collapse is that we need to understand a lot more about the behavior of skyscrapers and about fire, if we are going to prevent future tragedies. All of our witnesses today will call for an expanded federal research effort into the details of what happened at the World Trade Center and what that means for buildings generally. I wholeheartedly endorse that call. My colleagues and I will have many questions today about the nature, scope and financing of that follow-up effort, but I, for one, think we need to move forward with it.

We'll also do some of our own following up. I expect that the Committee will have a hearing on the report of the current Trade Center investigation when it is released in April, and we'll obviously continue to oversee the related activities of the agencies in our jurisdiction, and we'll pursue any federal issues that merit further review.

So, all of us here, I believe, understand that we are undertaking a heavy responsibility today by reviewing the response to the World Trade Center collapse. X September 11th is still a fresh wound. But this hearing is not about the past, it is about ensuring that we protect lives in the future. We are not here to point fingers, but to ensure that any problems that occurred in the wake of the Trade Center collapse do not hamper future investigations. We are here because the only way to move forward is to try to understand what happened on a day that was so incomprehensible.

develop Policy for a. clearly stated need

CONGRESSMAN SHERWOOD BOEHLERT (R-NY)
OPENING STATEMENT FOR WORLD TRADE CENTER HEARING
May 1, 2002

I want to welcome everyone here today to our second hearing on the collapse of the World Trade Center. In many ways, this hearing is a continuation of the discussions we began at our first hearing on March 6, and, indeed, we have the exact same panel of witnesses before us today as we did two months ago.

On March 6, we delved into the procedures that were followed to assess what had caused the towers to collapse in those indelible moments of September 11th. We were not happy with what we learned. We found that the study of the collapse had been hampered by bureaucratic confusion, hesitation and delay; by a lack of investigative tools and by excessive restrictions on the flow of information.

But we also learned that, despite these severe impediments, the team led by the American Society of Civil Engineers (ASCE), as well as other researchers, were able to draw some preliminary conclusions about the collapse, and that the National Institute of Standards and Technology (NIST) was willing to pick up where the ASCE team had left off, even though NIST officials couldn't tell us much at that point about exactly what that meant.

Today, we will pick up the story where we left off, focusing on three issues.

First, the ASCE team will describe the conclusions of their study – and it will become the subject of full-blown, public deliberation for the first time.

Second, NIST will tell us exactly what it intends to do in its follow-up investigation, for which the Administration has requested $16 million.

And third, we will release and open up the public discussion on legislation to ensure that the problems that hamstrung the ASCE study never, ever recur.

Let me turn first to the legislation, which I have drafted with Mr. Weiner. The bill, known as the "National Construction Safety Team Act," is designed to remedy each and every impediment that was encountered in the Trade Center investigation.

At the March 6 hearing, we uncovered four ways in which the status quo was unacceptable. First, no federal agency was clearly charged with investigating building failures. The bill solves that problem by giving NIST clear responsibility to handle the investigations. Second, nothing ensured that investigations would begin quickly enough to preserve valuable evidence. The bill solves that problem by requiring NIST to act within 48 hours of a building failure. Third, no federal agency had the investigative authority it needed to ensure access to all needed information. The bill solves that problem by giving NIST clear authority to enter sites, access documents, test materials and move evidence, as well as clear authority to issue subpoenas. Fourth, nothing ensured that the public was kept informed of the progress of the investigation. The bill solves that problem by requiring NIST to provide regular public briefings and to make public its findings and the materials that led to those findings.

We listened closely on March 6, and we have responded with a measure targeted precisely to remedy the issues that came to our attention. And we based the bill on a highly successful model – the National Transportation Safety Board, the federal agency that investigates airline crashes.

We want to begin to get comments on the draft bill today, and we intend to introduce it – along with several colleagues on this Committee and in the Senate – within about a week. I expect our Committee to approve the bill by the end of the month, and I would like to see it come to the House floor as soon as possible.

While the bill is mostly prospective in its focus, all the investigative tools it would provide to NIST, including subpoena power, would be available to conduct the World Trade Center investigation.

But what will that investigation entail? That's the key question this Committee needs to pursue today with NIST. There is an almost unlimited universe of questions that NIST could address, but time and money are not unlimited. NIST needs to focus on those matters that are most likely to result in changed codes and practices – including evacuation and emergency response procedures -- in a wide variety of buildings.

The investigation can't be driven by mere curiosity or political pressures, and it can't be based on the assumption that unlimited dollars will flow for future research. It has to be driven by the desire to save the maximum number of lives in the future – and to making the changes needed to save those lives as rapidly as possible. I hope that NIST will be able to assure us today that it is doing exactly that.

But regardless of the precise NIST agenda, the lab needs the $16 million that the Administration has requested for it in the Supplemental Appropriations bill that the House will consider later this month. The Administration is to be applauded for this request, although they have, unfortunately, complicated matters by asking that the money be provided to FEMA for transfer to NIST. We will work with the appropriators to get this money to NIST – directly, if possible; indirectly, if necessary.

So we still have plenty of questions as we pick up where we concluded on March 6. I want to assure the public in general, but especially the families of the victims, that this panel is committed to following this issue in the months and years ahead. We will not rest until we learn all we need to know to prevent future tragedies and until we implement what we have learned.

Let me conclude the same way I did on March 6: We are here because the only way to move forward is to try to understand what happened on a day that was so incomprehensible.

Statement
Hon. Ralph Hall (TX-4)
Committee on Science

Rep
~~Mr.~~ Weiner

Learning from 9/11: Understanding the Collapse of the World Trade Center
26 February 2002
Committee on Science Hearing

I want to join Chairman Boehlert in welcoming everyone to this afternoon's hearing.

Today's hearing will focus on the aftermath of the cowardly attacks on the World Trade Center and the Pentagon, which will rank as one of the great tragedies in American history. As with any tragedy we try to find some shred of consolation by looking to lessons that can help protect us against possible future tragedies. We need to carefully examine our emergency preparedness, evacuation procedures, and emergency response as well as the structural integrity of tall buildings as we sift through the events of September 11 in our search for meaning.

Today we will focus on the procedures and efforts to collect data at the World Trade Center site. I want to learn how we about the problems encountered by the structural assessment team and what changes need to be made to our procedures. I understand that we need to improve the coordination between all the Federal, state, and local agencies that were on-site. Important information was lost during the first month and we need to ensure this doesn't happen again. I also believe that NIST needs to play a more active role in the follow-up assessment and research that is required. NIST should serve as a pro-active liaison to the building code community to ensure that findings of the structural analysis in this case are reflected in our building codes.

I would like to thank the members of the FEMA Building Performance Assessment Team assembled by the American Society of Civil Engineers. These distinguished professionals have volunteered their time to work on this team. Volunteers from the Structural Engineers Association of New York have also assisted them. This isn't the first time a group of professionals have volunteered their time and expertise to serve on a FEMA assessment team. However, this is one of the few opportunities we have had to publicly thank them for their services. The FEMA team's report isn't due until April and their work is ongoing. It may be that the Committee has questions the witnesses don't feel ready to answer--I hope that we will keep at this issue so that we get answers as they become available. It is particularly important that we do follow-up work on any recommendations that the FEMA team offers. I hope this Committee will hold subsequent hearings to review the implementation plans for the research and analysis phase.

I would like to offer my condolences to the families of the victims of this tragedy, some of whom are at this hearing. You have suffered a terrible loss. This Committee will continue to follow the issue of disaster response and building safety to ensure that the lessons learned form the World Trade Center Disaster will be implemented to improve building safety codes, emergency response and evacuation procedures.

I would now like to yield 2 minutes each to Rep. Weiner and Rep. Steve Israel. (b)(6)

NTSB powers to NIST

(b)(6)

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March 6, 2002

Mr. Mitchell E. Daniels, Jr.
Director, Office of Management and Budget
Old Executive Office Building
Washington, D.C. 20501

Dear Mr. Daniels:

We are writing to you as a result of today's House Science Committee hearing on the collapse of the World Trade Center buildings. There was unanimity among the witnesses on the need for a comprehensive assessment and research agenda to address evacuation procedures, emergency response, and structural analysis of the site's buildings. The goal of such a study would be to improve the safety of both the public and the emergency responders in the event of another building collapse.

We understand that the National Institute of Standards and Technology (NIST) has submitted a proposal for a comprehensive follow-on study. Dr. Arden Bement, NIST Director, stated at the hearing that NIST had received policy approval for such an initiative. However, we are concerned that NIST does not have the financial resources to implement its plan. Although NIST has allocated $2 million for its efforts, the Federal Emergency Management Agency's (FEMA) Building Performance Assessment Team (BPAT) has estimated that $40 million would be required to fund a comprehensive study of an event of this magnitude and complexity. We urge you to provide NIST with the funding required. The NIST proposal is fully consistent with the Administration's focus on Homeland Security and would benefit all Americans.

We have also been troubled by accounts that the BPAT did not have immediate access to the World Trade Center site. As a result, structural steel artifacts were destroyed that may have been important to the investigation. BPAT's access to architectural drawings critical to its investigation was also delayed. NIST or FEMA should have investigative authority (akin to the National Transportation Safety Board) to ensure that similar problems do not arise again.

We look forward to your response regarding funding for NIST's proposed activities and your views on vesting FEMA or NIST with authority to allow them to fully fulfill their duties.

Sincerely,

SHERWOOD L. BOEHLERT
Chairman

ANTHONY WEINER
Member of Congress

STEVE ISRAEL
Member of Congress